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The Month.

THE SIMPLON TUNNEL.—The most noteworthy event of the past month certainly was the passage of the first railway train through the Simplon tunnel, which was finally completed on January 22nd., so far as concerns structural work. A minute inspection of the roof and walls is now being made and the work of laying cables for traction and other purposes has been commenced. The arrangements for ventilation are interesting, and it is to be hoped that the apparatus will prove successful, for upon its efficiency much depends. The north end of the tunnel is closed by a tightly fitting curtain of stout canvas secured to an iron frame sliding on rollers and operated by an electric motor. Powerful fans driven by turbines are installed at the same entrance and are capable of discharging about 2,400 cubic feet of air per second into the tunnel. Similar fans will be provided at the south entrance and used for exhausting, so as to increase the velocity of air forced in at the other end. At the present time air passes freely from the south entrance, but this will be closed by a curtain. The fans are working at little more than half their maximum capacity and of course have no assistance from the other end of the tunnel. Hence the reports published as to the temperature of the air afford no criterion as to the temperature to be expected when everything is in full working order. There seems to be every reason for supposing that the system of ventilation should be entirely satisfactory.

SHIPBUILDING ON THE THAMES.—In speaking at the opening of the London County Council School of Marine Engineering, Sir William White availed himself of an excellent opportunity for reviewing the past history of the Thames as a great centre of the shipbuilding industry. For centuries the district took the lead in the construction of ships for war and commerce, and even thirty or forty years ago there were many large shipbuilding yards on either shore of the river. Most of these have disappeared and in the present day the total annual output is less than 12,500 tons, as compared with 540,000 tons on the Clyde, 350,000 tons on the Tyne, 317,000 tons on the Wear, and 140,000 tons at Belfast. No doubt geographical situation and other natural conditions have a great deal to do with the decadence of the Thames as a seat of shipbuilding. High rates of wages and the increasing burden of local rates are even more responsible, as proved by the final decision of Messrs. Yarrow to remove their works to the Clyde. Of course a large amount of repair work will always remain

in a port like that of London, and for this skilled men are required. Therefore it is not entirely wasted effort to establish a school of marine engineering. But we imagine that the benefit of the new institution will be experienced as much in other shipbuilding districts as on the Thames, and it is somewhat questionable whether the London County Council were justified in expending the public money on a project of the kind, however admirable may be its object.

DESTRUCTOR BY-PRODUCTS.—In a paper read before the Civil and Mechanical Engineers' Society, Mr. F. L. Watson discusses the utilisation of the various by-products from which some return may be obtained as a set off against working costs. The author justly points out that however valuable such a contribution may be, we must rid our minds absolutely of the foolish idea which seems to possess many people that a destructor plant is to be looked upon as a desirable financial investment apart from its sanitary value. After heat, which has been very largely used for steam raising purposes, the most important by-product is clinker. Samples of this material were exhibited by the author in grades suitable for such purposes as road sanding, concrete making, and the basis of sewage filter beds. Clinker flags and mortar are employed with considerable success by many municipal authorities, and if engineers generally recognised its utility as an aggregate the owners of destructor stations would doubtless be pleased. One of the most promising directions in which clinker can be employed is in the manfacture of artificial bricks somewhat on the lines of the lime-sand brick process so popular in Germany, and we understand that the system of brickmaking patented by Dr. Schulthess, of Zurich and Paris, is now being introduced into this country for the utilisation of destructor clinker. Some of the bricks so made have been tested at the Engineering Laboratory of Leeds University and show a tensile strength of from 110 tons to 180 tons per square foot, and an absorption of less than 5 per cent. after soaking for twenty-four hours in water.

THE THEORY OF LUMINOSITY.—In his lecture at the Royal Institution on "Some Applications of the Theory of Electric Discharge to Spectroscopy," Professor J. J. Thompson explained in a very striking manner some of the results obtained by the series of elaborate investigations conducted at the Cavendish Laboratory, Cambridge, with respect to the mechanics of luminosity. According to the theory set forth by the lecturer, luminosity is attributable to a critical value to which the internal energy of an atom must be raised. On the other hand while temperature measures the energy of translation of an atom, yet a certain equilibrium must exist between this form of energy and the internal energy, and given a sufficient increase of the energy of translation, a portion of this energy may be transformed into internal energy and so give rise to luminosity. The advantage of exciting luminosity by electricity is that the addition of energy is made in the first place directly to the internal energy of the atom, the condition of equilibrium between this and the energy of translation being established by the partial transformation of internal atomic energy. When employing the ordinary method of exciting luminosity by increase of temperature the converse is the case. A concluding requirement was of special interest owing to the light which it appeared to throw upon the actual nature of the arc. In this experiment the lecturer employed a tube containing a calcium electrode, the discharge of the tube increasing with the increased temperature of the cathode. It was shown that if the discharge were sufficient the temperature would be further augmented by impact of positive particles from the anodes and that the automatic increase of discharge would finally culminate in the formation of an arc.

THE FLAMING ARC.—As a means of illumination capable of competing successfully on the score of economy with the cheapest form of gas burner or lamp, the flaming arc introduces quite a new feature into the practice of electric lighting. No doubt a good deal of experimental work will have to be done before the peculiarities of the new light are as fully understood as well as those of the ordinary arc, but enough is already known to make its use perfectly practicable for outdoor lighting. At present the flaming arc emits fumes to such an extent as to render its employment undesirable in ordinary buildings. If this disadvantage can be obviated, even the most economical form of gas burners will have to face very severe competition, particularly as the new illuminant permits considerable variation of colour and should provide an agreeable change from the greenish hue of Welsbach lights. The appearance of the flaming arc is certainly somewhat startling,

and by its side an ordinary arc lamp or the most powerful gas lamp is as completely paled as the moon in the broad light of day. The pale golden hue of the light is a pleasant change from the blue of the enclosed arc and the enormous volume of rays dispersed renders the flaming arc exceedingly suitable for the illumination of open spaces and large interiors such as railway stations and some public buildings. To give an idea of its efficiency we may say that the flaming arc gives from five to ten times as much light per watt as an ordinary arc lamp. Those of our readers who desire further information on the subject cannot do better than to read the excellent paper read by M. Blondel at the International Electrical Congress, 1904. This authority was able to obtain results showing an efficiency of 0·125 watt per mean spherical candle-power.

THE FOREIGN CEMENT DANGER.—In different parts of the Continent mineral deposits are found which lend themselves to the economical production of "natural" cement, which is of variable quality and far inferior to properly manufactured Portland cement. Natural cement is largely made in Belgium for exportation to this country under the falsely applied designation of Portland cement, and the packages in which it arrives here are very generally marked in such manner as to lead buyers to suppose that they are receiving a British made product. Unfortunately, the Merchandise Marks Act contains loopholes permitting fraudulent devices of the kind, and the customs authorities seem unwilling to enforce the obvious intention of the Act owing to some punctilious idea begotten of red tape. The matter is a very serious one for British cement manufacturers, and also for the public generally, because most of the cement used by builders under the so-called supervision of architects is not subjected to any tests, and if the users are supplied with a powder which looks like the genuine article and sets in an apparently satisfactory manner, they raise no questions as to its strength or durability. Builders are naturally anxious to buy in the cheapest market, and until architects begin to insist upon proof that the cement used comes up to the British standard, there is not much likelihood that the popularity of low-priced Belgian cement will be seriously diminished.

TRAMWAY BRAKES.—The tramway accident at Liverpool is only one of various other occurrences pointing to the necessity of really efficient brakes, especially on steep gradients, and we feel sure that engineers will generally welcome the paper which was read on the subject by Mr. A. L. C. Fell before the Tramways and Light Railways Association. The question of brakes has received much attention during recent years and great improvements have undoubtedly been made. Still, it is the fact, that with heavy vehicles and the increased speeds that are now being adopted, more efficient brakes are an absolute necessity. The trials made on the London, Brighton and South Coast Railway in 1878 constitute the first reliable attempt to arrive at a scientific solution of the problem involved in the efficient braking of vehicles running on rails. In his paper Mr. Fell reproduces two of the curves relating to the effect of skidding as demonstrated by these experiments. The curves in question prove, what was already well-known by railway engineers, that the friction between the wheel and the rail when the former is sliding is very much less than the friction between the brake blocks and the wheel when the latter continues to revolve. As a matter of fact the friction during skidding is less than one-third of that caused by the normal action of brakes, and tramway engineers must recognise this fact if they wish to provide for the new conditions of traffic. Mr. Fell refers briefly to the more prominent types of tramway brakes which have lately been tested in an exhaustive manner on a section of the London County Council tramway system, the trial car being equipped with suitable instruments calibrated at the National Physical Laboratory. From the results obtained it is clear that hand and rheostat brakes do not compare with electromagnetic brakes. One great advantage offered by the latter is, that they can be used in the densest traffic when the cars are travelling at very low rates of speed. Several points in connection with the design of such brakes require careful attention. For example, it is necessary that provision should be made for applying the brakes very gradually, that the connections on the controller are entirely disconnected from the power circuit, and that there shall be no risk of short circuiting when one motor has been cut out. Another matter to be remembered is that brakes of this type require careful handling, as unless carefully applied severe strains will be caused in the car bodies and especially in double-decked cars fitted with roof covers.

THE OVER-PRODUCTION OF ENGINEERS.—For generations past the overflowing ranks

of various professions have formed the subject of complaint. That such a state of things should have existed when the only professions recognised were the army, the church, and the bar, is only natural, but when the lower branch of law and medical practice grew into respectability there came an inevitable rush for admission, and similar results have followed the elevation of architecture, surveying, and engineering to professional rank. So great is the desire to avoid the stigma wrongly supposed to be connected with trade that many other callings are now classified as professions, with the result that most of them have become overcrowded with superior young men, who find increasing difficulty in solving the great problem of how to get on in the world. At the present time the engineering profession suffers severely from over-production in this way, from the pupil with an expensive university training, followed by tuition in the office of some eminent engineer, down to the polytechnic student who has served his time in the workshops. Offices and workshops alike are crowded with youths who want to get on and to earn fame as civil, mechanical, electrical, or even as motor-car engineers. A reaction may set in some day, but certainly not until the existing glut has been considerably increased. Judging from the American press, things are just as bad on the other side of the Atlantic, where far more students are being trained for professional work than can possibly find employment. The result there, as at home, is severe competition between older men and new recruits, and by the time those of the latter who survive have managed to make headway they have in turn to face the competition of a fresh supply of aspirants. The position is one for which it is difficult to find a really efficient remedy, although the compulsory registration and qualification of practising engineers, and the establishment of organisations like those associated with the legal and medical professions would do much to improve matters.

THE LIVERPOOL TRAMWAY ACCIDENT. —None of the witnesses examined at the Board of Trade inquiry were able to suggest any reason for the serious derailment which took place in December last at the corner of Leece Street and Renshaw Street, Liverpool. It was stated that before the car left the depôt the hand and electric brakes were tested, and found to be in good order. Yet when the driver had proceeded ten yards down the hill the electric brake appeared to fail him entirely. The application of sand, the reversal of the motors, and the use of the hand brake were of no use, and at the time the car left the rails it had attained a speed of nearly seventeen miles an hour. Examination after the accident showed that the brakes were in proper order, and the only inference is that they were not of sufficiently powerful character, or perhaps had been applied so as to cause the wheels to skid, thereby reducing the grip on the rails. The question of tramway brakes is clearly one that demands most serious consideration, in view of the increased weight of vehicles and the extension of the tramway system in large cities and towns.

AMERICAN STANDARD RAILS. — Since the rail sections of the American Society of Civil Engineers were settled in 1893, there has been ample time for the formulation of opinion as to their general suitability. During the year 1905 reports have been received from seventy-nine of the leading railway companies of the United States, Canada, and Mexico, as to results obtained in the use of the sections recommended. Some criticisms are made as to the shape of the head, the thickness of the web, and the width of the base; but as forty-eight companies have adopted the sections as their standard, and fifteen other companies propose to do the same, there is evidently a generally favourable opinion as to the merits of the sections. Consequently the Committee on Rails think it unnecessary to recommend any modifications. On the question of the chemical constitution of steel for rails the committee favour a high percentage of carbon, ranging from 0·50 per cent. for 70-lb. rails to 0·65 per cent. for 100-lb. rails. Such percentages are certainly calculated to give hardness, but the rails, especially in the heavier sections, will be somewhat brittle, and so increase the number of breakages, already fairly heavy in America. It would probably be better to adopt lower carbon percentages than those now recommended, together with such requirements as would involve lower temperatures in rolling than are now customary. We believe that many of the failures which have taken place in the past are attributable to unequal temperatures during rolling, due to the relatively large section of the head as compared with the section of the web and bottom flange. These are important matters to which the society might well devote consideration before finally confirming the report of their committee.

The Logarithmic Chart.

By WILLIAM J. GOUDIE, B.Sc., A.M.I.Mech.E.

WHEN charting any expression, the aim of the constructor should be to produce, not only a combination of diagrams giving results with the least expenditure of time and labour, but also to so arrange the elements of the problem that the preliminary calculations and work of construction are reduced to a minimum.

The majority of engineering expressions, sufficiently important to be embodied in chart form, are of the factorial character, that is, each side of the equation usually consists of a continued product, in which several factors may occur to the first power, and several to powers greater or less than the first.

When those factors, whose exponents are not unity, are chosen as constants, a straight line chart can usually be drawn down on ordinary squared paper; and this type, which is easily and quickly produced, leaves nothing to be desired from the constructional point of view.

It sometimes happens, however, that the inevitable convergency of each set of curves to its respective origin, and the crowding together of the lines on this part of the field of co-ordinates, more or less impairs the usefulness of the combination; and when this is the case, the defect can be easily remedied by the substitution of the logarithmic for the uniform scale when plotting the values of the current co-ordinates. The straight line character of the chart is not affected by this change, and each component diagram consists of a series of lines which are parallel instead of converging to a point.

The parallelism of the lines also tends to the simplification of the work of construction. After one line of any diagram has been drawn in, all the rest can be drawn parallel to it when one point on each line has been located. Besides obviating the crowding defect, the employment of the logarithmic scale gives a chart of more reasonable size than can be obtained when a uniform scale, covering a wide range of values of the variables, is used. When the size of the uniform scale has to be restricted, the accuracy of the readings is apt to be impaired; this drawback does not occur when the logarithmic scale is used.

Some of the most important expressions constantly used by the mechanical engineer, cannot, however, be *wholly* charted in the straight line form; and when these have to be dealt with, the logarithmic is much to be preferred to the older, and apparently simpler "squared paper" method.

In such cases it is often necessary to calculate out a number of values of the current co-ordinates for each of a series of curves, and this calculation and subsequent plotting and curve drawing is a tedious and patience-testing process. The logarithmic method of chart construction eliminates the major portion of this labour; and the writer is of the opinion that if it were better known it would be more generally adopted than it is at present.

As just pointed out, instead of half-a-dozen or more points being required for each curve which is not a straight line on the ordinary diagram, only one is necessary on the logarithmic diagram, after the slope of the initial curve of the set has been ascertained. When the same logarithmic scale is used for each variable, the slope of each set of curves is dependent on the index of the power of the variable, and it may happen that the inclination to the horizontal or the vertical is insufficient, to enable the points of intersection with the horizontal or vertical lines to be as

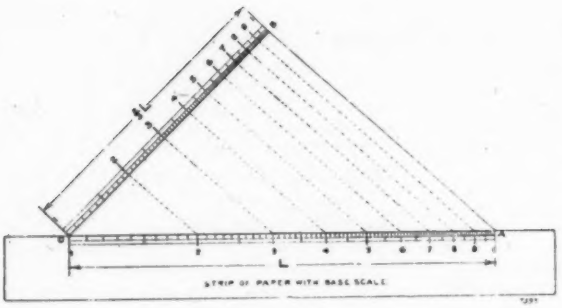

FIG. 1.

accurately determined as they should. The best angle of inclination for the curves of each diagram is obviously 45 degrees; and when the dimensions of the scales of the variables are made proportional to the indices of their powers, the proportional increase or decrease in scale dimensions reduces the varying slopes of *all* the series of curves to this common one of 45 degrees. Under these conditions, it is hardly necessary to point out how easily and quickly each diagram can be drawn in with the aid of the T and 45 degree set squares, when one point is given on each curve.

Where the index of the constant factor is unity, it will usually be found that the single point in each curve can be located without any preliminary calculation, and that the set of curves can be drawn in as soon as the necessary logarithmic scales have been laid off on the axes of the chart. Where the constant occurs to the second or third, or the corresponding fractional powers, the points can likewise be located without calculation, by laying off the values from a table, at the unit, ten, hundred, or thousand value of the variable. In fact, for the majority of cases it will be found that the calculative work is practically eliminated.

With regard to the logarithmic scales, and the reduction or increase of their dimensions to satisfy the condition just specified, every chart constructor who possesses a slide rule has the necessary base scale ready and accurately made to his hand.

This can be transferred from the rule, in a few minutes, by placing the edge of a strip of paper along it, and ticking off the divisions with a pencil. From this scale any number of logarithmic scales of different dimensions can be easily obtained, by the simple geometrical construction for the proportional division of lines. The length of the slide rule scale between 1 and 10, or 10 and 100, is a *unit* length, and the lengths 1 to 2, 1 to 3, 1 to 4, &c., represent the fractional parts of this unit length corresponding to the mantissæ values of the logarithms of the division numbers 2, 3, 4, &c., in the logarithm tables. To obtain a scale which will be any multiple of the base scale, it is only necessary to take a new unit length, equal to the required multiple of the base unit, and to sub-divide it in the same proportion as the base scale unit.

Suppose, for example, it is desired to construct a logarithmic scale two-thirds the dimensions of the base scale (say the lower scale of a 10 in. slide rule).

Tick off the scale $OA = L$, Fig. 1, on the edge of a strip of paper, and pin this strip with a sheet of paper on a drawing board. Then draw $OB = \frac{2}{3} L$, the new unit length, at any convenient angle to OA, and join A and B. From the scale divisions on OA draw parallels to AB as indicated by the dotted lines; complete the division lines and figures on OB, cut the paper along this line, and the two-thirds scale is ready for use. From this example, it will be seen that with little trouble the constructor can line out a set of standard scales, which he can have available at any time, for the construction of a logarithmic chart.

As a practical illustration of the foregoing methods, a logarithmic chart,

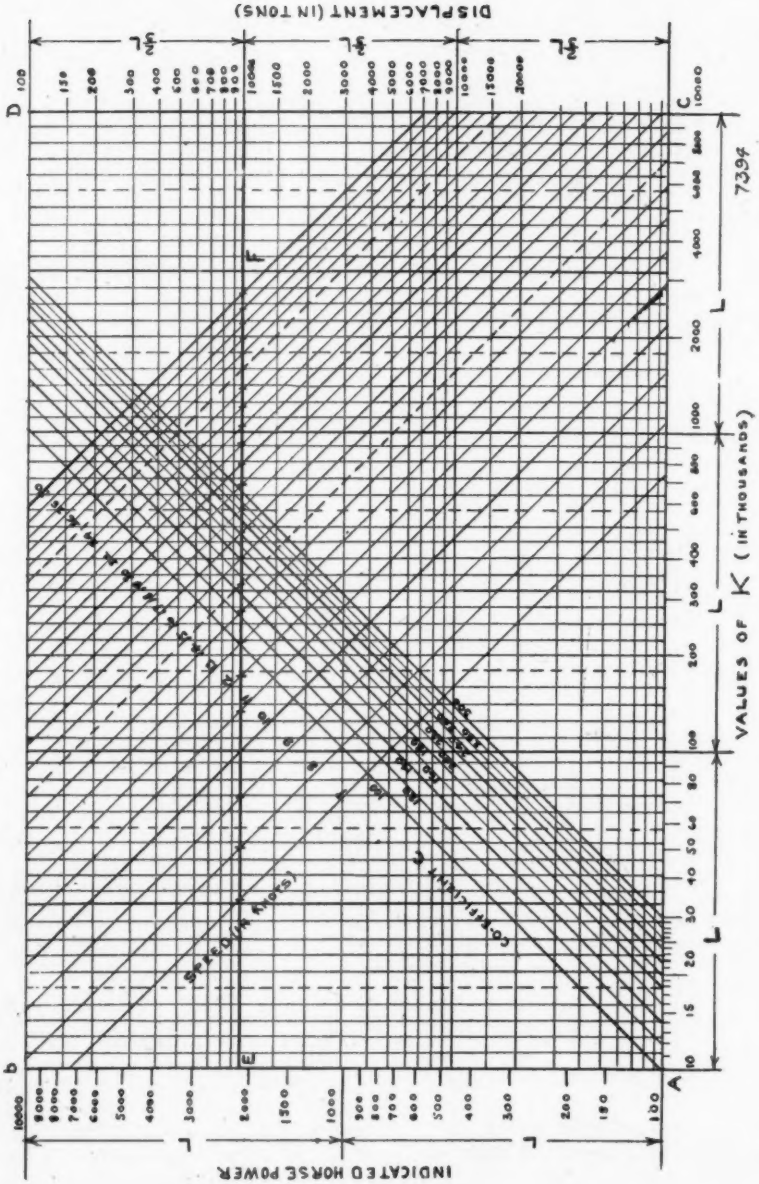
DISPLACEMENT (IN TONS)
INDICATED HORSE POWER
VALUES OF K (IN THOUSANDS)
7394
SPEED IN KNOTS
COEFFICIENT C
A
B
C
D
E
F

FIG. 2.

embodying the well-known expression for the power and speed of ships, has been drawn down on a small scale, and is shown at Fig. 2.

This expression is typical of the class previously referred to, and a short review of the various steps in the construction of this chart will indicate sufficiently the detailed method of procedure for similar cases.

The expression to be charted is,

$$H = \frac{D^{\frac{2}{3}} S^3}{C},$$

where $\begin{cases} H = \text{Indicated horse-power.} \\ D = \text{Displacement in tons.} \\ S = \text{Speed in knots.} \\ C = \text{A co-efficient.} \end{cases}$

In this case there are four factors. The invariable rule in chart construction is this, that where n elements or factors are involved the chart will consist of $(n-2)$ sets of curves or interlinked diagrams. In other words, two of the factors are variables and the rest are constants. In selecting the constants the constructor, *where the nature of the solution admits*, should choose those which have the smallest ranges of values, and therefore involve the least number of curves per set. If the factor, which has usually to be determined, has a small range of values, it is *not* advisable to choose it as a constant, as this arrangement would entail a *break* in the continuity of the operation when determining its value on the chart.

This chart will consist of two diagrams, and may be termed a "two-stage" one.

The practicable ranges of values of the factors may be taken as follows:—

H	from	100	to	10,000
D	,,	100	,,	20,000
S	,,	7	,,	30
C	,,	100	,,	300

Obviously, the least number of curves per diagram will be given by the choice of S and C as constants; and as H is usually the value required this selection, with H and D as variables, will ensure continuity in operating the chart. The next step is to obtain the equation for each set of curves.

Where, as in this case, the expression involves four factors it can be written down on an equality between the products of two pairs of the factors, thus,

$$H\,C = D^{\frac{2}{3}} S^3 = K, \text{ giving}$$

$H\,C = K$ (1), the equation for the co-efficient curves.

$D^{\frac{2}{3}} S^3 = K$ (2), the equation for the speed curves.

In equation (1) the exponent of both H and K is unity, and their co-ordinate values are plotted from the same logarithmic scale. Since the exponent of C is also unity, it will be found that no calculation is necessary to obtain the values of K for the C set of curves.

Referring to Fig. 2, lay off on $A\ B$ the values of H, beginning at A with the 100 value, and on $A\ C$ the values of K, beginning with the 10,000 value.

When $H = 100$ and $C = 100$, $K = 10{,}000$, so that the line at 45 degrees through the 10 value on the K scale gives the curve $C = 100$; and it will be evident that, for all values of C between 100 and 300, the parallel lines through the 11, 12, 13, &c., values on the K scale will give the 110, 120, 130, &c., co-efficient curves.

In equation (2), the exponent of D is $\frac{2}{3}$; and since that of K is unity, the logarithmic scale for the D values must be $\frac{2}{3}$ the dimensions of the K scale, to give the 45 degree angle diagram.

Lay off on $D\ C$ the displacement values from the $\frac{2}{3}$ scale, beginning with the 100 value at D, which may be any arbitrarily chosen point on $D\ C$.

In this case the exponent of the constant S is 3; but as the cube values can be directly obtained from a table, the construction of this second diagram is as easy and rapid as that of the first one.

Taking $D = 1{,}000$, then $D^{\frac{2}{3}} = 100$. When $S = 10$ then $K = 100{,}000$, and the curve for $S = 10$ will be given by the line at 45 degrees through the intersection of the 100 vertical and the 1,000 horizontal. By placing the K scale along $E\ F$, with the 10 value on E, the rest of the points, for the speed curves between 7 and 30, can be located by ticking off

the cube figures given in the tables. For example, the first point, for the 7-speed curve, would be marked at the 34·3 division of the scale.

The points could, of course, be obtained by projecting from the K scale on $A\ C$; but the method described is obviously the more suitable of the two. The points being marked along $E\ F$ the speed diagram can then be drawn in with the aid of the 45 degree set square.

When the horizontals through the displacement values and the suitably spaced guide verticals are drawn in across the chart, and the scale values marked, the combination is ready for use.

The final "squaring" is the only saving effected by the use of ordinary squared paper; but this is a trifling matter when compared with the saving of time calculation and labour in drawing down the speed diagram on the logarithmic chart.

The rule of operation for this chart may be stated thus:—

(1) Follow the horizontal from the displacement scale to the speed curve.

(2) Follow the vertical from the speed curve to the co-efficient curve.

(3) Follow the horizontal from the co-efficient curve to the horse-power scale and read the result.

Some of the expressions belonging to the same class as the foregoing involve five factors; but it is seldom that a six factor expression of the purely factorial type has to be charted.

To illustrate how such a five factor expression may be manipulated for charting purposes take that, given by Seaton and Rounthwaite, for estimating the diameter of a screw propeller.

$$D = C\sqrt{\frac{H}{\left(\frac{P\,R}{100}\right)^3}}$$

where
- D = Diameter in feet.
- H = Indicated horse-power.
- P = Pitch in feet.
- R = Revolutions per minute.
- C = A co-efficient.

There are five factors here, and there will therefore be three diagrams in the chart. In this instance, since D is the usual quantity required, it is advisable to take D and H as variables, because the choice of D as a constant would, as already mentioned, break the continuity of operation when estimating its value.

After squaring each side, the equation may be written,

$$D^2\left(\frac{R}{100}\right)^3 \times \frac{1}{C^2} = \frac{H}{P^3} = K, \text{ that is}$$

$D^2\left(\frac{R}{100}\right)^3 = C^2K = X$, and $\frac{H}{P^3} = K$. so that

$D^2\left(\frac{R}{100}\right)^3 = X$ (1) is the equation for the revolution diagram.

$C^2K = X$ (2) is the equation for the co-efficient diagram.

$\frac{H}{P^3} = K$ (3) is the equation for the pitch diagram.

Equations (1) and (2) will give a two diagram chart, similar to that at Fig. 2, while equation (3) will give a single diagram one, which will be linked with the first chart through the medium of K. Also, since the exponent of the variable D is 2, and that of H is unity, the D scale will be twice the dimensions of the H one.

In the construction of the chart, the D scale can be laid off along $A\ B$ (Fig. 2) between the 2 and 20 values, the scale of 2 L dimensions being used, and the X scale along $A\ C$, between the 10 and 1,000 values, the scale of L dimensions being used. The revolution curves can then be drawn in the same way as the speed curves (Fig. 2).

The K scale can be laid off from D along $D\ C$ between the 1 and 100 values, the scale of L dimensions being used. The co-efficient curves can then be drawn in. Finally, the H scale can be laid off from C, or AC produced, between the 100 and 10,000 value, the scale of L dimensions being used, and the pitch curves can be drawn again in the same way as the speed curves on Fig. 2.

There are some expressions which cannot be satisfactorily charted, by the employment of either the uniform or the logarithmic scale; but such difficulties can usually be overcome by a combination of the two.

The "Mees" Gas Engine.

By Dr. ALFRED GRADENWITZ.

Two processes of regulation have so far been used in connection with gas engines, namely, the so-called mixing regulation, where the mixture ratio of the charge consisting of gas and air is altered, and the more recent charge regulation method, where the amount of the charge itself is altered, while the mixture ratio of the same remains constant.

There are drawbacks inherent in both of these methods. The mixture process, which is especially available in connection with high compressions, shows the disadvantage that ignition becomes more and more uncertain and unreliable as the load of the motor decreases, a large waste of energy being involved by the imperfect combustion of the mixture. This is why explosion motors are of late years regulated in many cases by the charge regulation process, which, however, possesses the drawback that the cycle becomes less and less satisfactory as the compression decreases with the load, while on the other hand it is impossible to ensure constant satisfactory effects with all loads, owing to the constant mixture ratio.

A very suitable combination of the two above methods, where the advantages of both are maintained, while eliminating their inconveniences, has been recently patented by Herr Mees of Düsseldorf. The "Mees" gas engine which is represented in the accompanying figures, draws in with normal loads a relatively weak mixture, which, however, is still susceptible of ready explosion, and which is submitted to a sufficiently high tension with the compression stroke. Now a high compression and a weak mixture are known to be the most important requirements for insuring a satisfactory utilisation of the heat. The motor will, therefore, like a steam engine, work at normal loads under the most favourable conditions, requiring the smallest consumption of fuel per i.h-p. hour. Now, though this figure is altered somewhat owing to friction, it may be considered as practically constant from about 70 or 80 per cent. of the maximum load up to the latter. As the maximum load is reached, the motor will draw in a very rich mixture, thus increasing the efficiency at the cost of the fuel consumption, considerably beyond the normal figures. With low loads the motor finally draws in a charge of normal composition and of varying amounts, compressing this more or less according to the load, but in

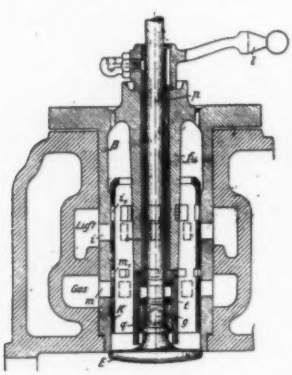

FIG 1.

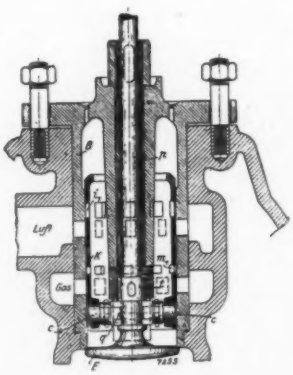

FIG. 2.

any case much more so than any motors regulated exclusively on the charge process.

The constructive details of the regulation apparatus are seen from Figs. 1 and 2. The admission valve *E* arranged at the upper part of the cylinder head, is actuated by a cam disc keyed to the countershaft by means of a roller lever, connecting rods and angle lever (see Fig. 13). To lock the air channels, *i*, and the gas channels, *m*, arranged in the cylindrical valve seat, *B*, a piston slide, *K*, is used, connected to the admission valve by a tappet, *q*, and which is thus compelled to follow any motion of the valve, opening and locking the channels referred to by means of corresponding channels, *il* and *ml*, as the valve is opened and locked.

This slide is, however, not only a locking, but at the same time a regulating device. To this effect a hollow box, *p*, which is free to rotate in the valve guide, *f*, extends by its lower forked end, *g*, above the tappet, *q*, turning on the valve spindle, and being connected by the pin, *c*, to the piston slide. At the upper end of the hollow box, there is fixed a regulation lever, *l*, which communicates with the governor. In an axial direction, the tappet, *q*, freely moves in the fork, *g*. By means of the ring, *t*, which is rigidly connected to the valve spindle by a wedge, it is compelled to follow any vertical reciprocating motion of the valve. If the governor displaces the lever, *l*, the hollow box, *p*, the tappet, *q*, and accordingly the piston slide, *k*, will be rotated correspondingly, so that the free cross sections of the channels, *i* and *m*, giving access to the air and gas are increased or reduced in accordance with the load. If the ratio of the open cross sections of these channels be the same with all positions of the rotary slide, the mixture ratio will remain unaltered with variable charge and variable compression,

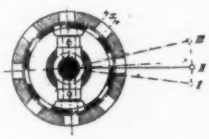

FIG. 3.

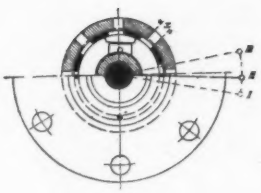

FIG. 4.

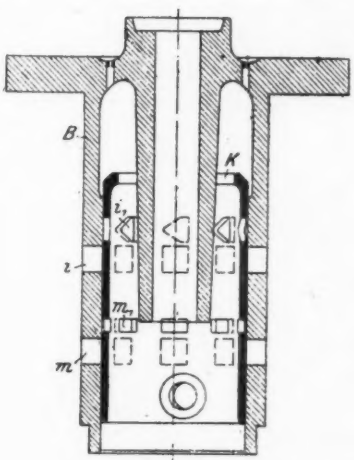

FIG. 5.

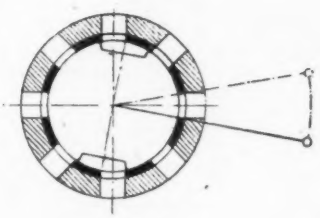

FIG. 6.

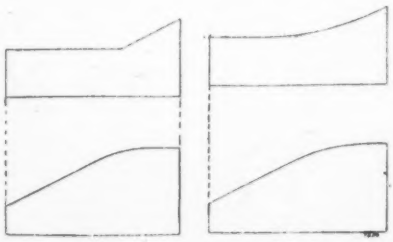

FIG. 8.

FIG. 9.

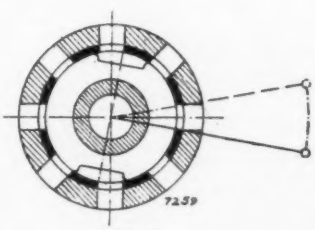

FIG. 7.

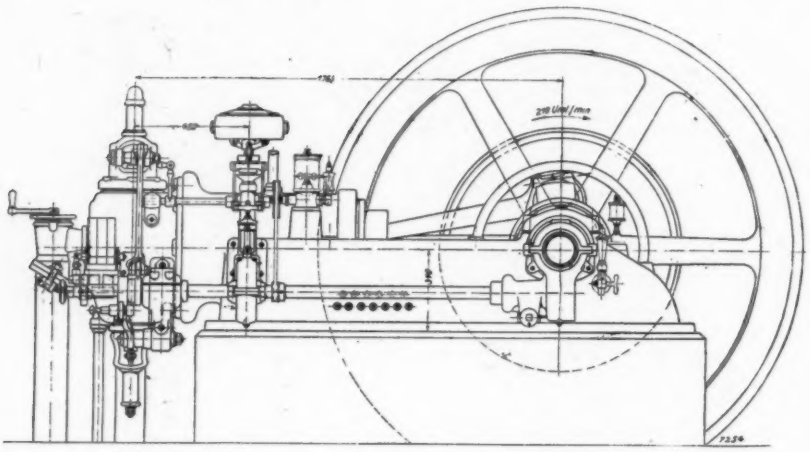

FIG. 10.

FIG. 12.

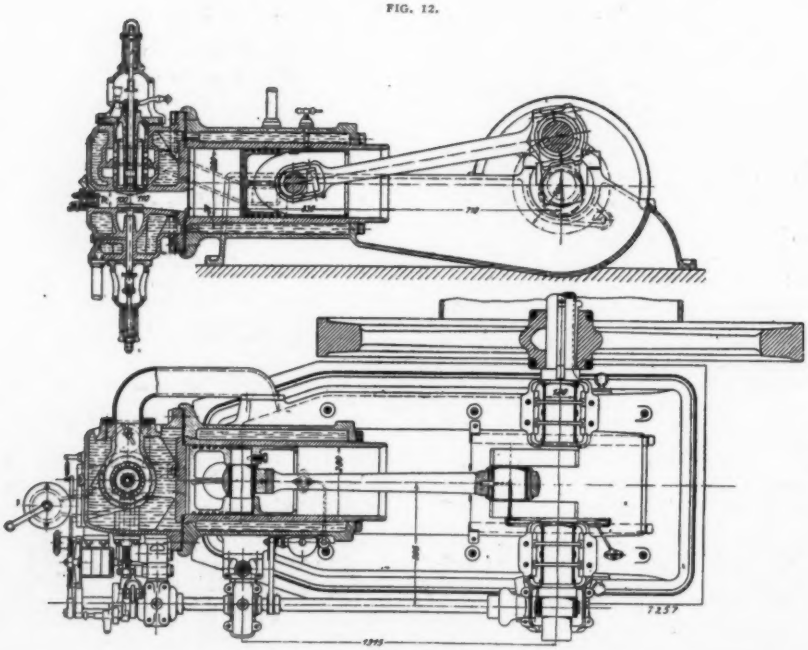

FIG. 14.

when there will be exclusively a charge regulation. This will be true in case the air and gas channels in the sliding box and the slide have the same length, and a rectangular shape, when the mixture ratio will depend exclusively on the height of the channels.

Regulation by an alteration of the mixture ratio with constant compression can be obtained by the same means. In this case, the rotary slide would have to be used to throttle the gas admission through the channels, *m* and *ml*, while the air channels are always kept open entirely. The slide, *K*, would, in that case, be made shorter than as shown in Figs. 1 and 2. In order to combine the two methods of regulation, the air channels, *i* and *il*, as well as the gas channels, *m* and *ml*, should be so calculated that during the first part of the rotary motion of the slide, *K*, corresponding with the higher load of the motor, only the gas is throttled, while only during the later stage of the rotary motion (corresponding to smaller loads on the motor) the gas and air are throttled simultaneously in nearly the same measure.

The slide represented in Figs. 1 to 4 has been designed according to the above principle. In Fig. 3 is shown a cross-section through the gas channels, *m* and *ml*, and in Fig. 4, a section through the air channels, *i* and *il*, of the slide box and the slide respectively; the latter will be seen to be considerably shorter than the former. By properly calculating the height of the channels, the mixture ratio can be adapted to the heat value of the gas.

In the positions represented in Figs. 3 and 4, the rotary slide has locked a considerable part of the gas channels, *m*, while keeping fully open the considerably shorter air channels, *i*. The gas has accordingly been strongly throttled from the original position, *I*, of the slide and regulation lever, as corresponding to the maximum load of the motor, while the air admission has been little altered during this path. On the path from position *I* to position *II* of the rotary slide, regulation is accordingly affected by altering the mixture ratio. In the position *II* of the rotary slide, the length of the open part, *x*, of the gas channels, will strictly correspond to the open length of the air channels, *i*, which have been also denoted by *x*. Now as the regulation lever and along with this the slide is proceeding towards position *III* (no load), on the engine being further unloaded, the gas and air channels, *m* and *i*, will be locked in exactly the same

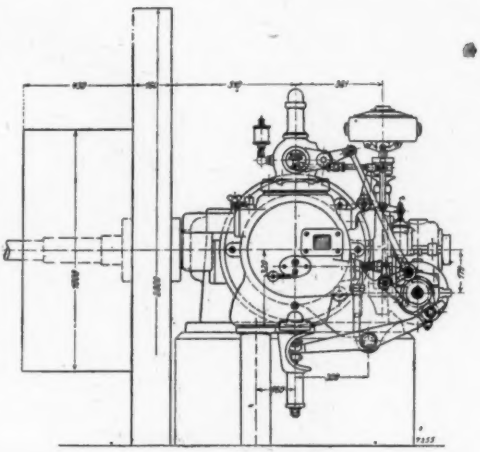

FIG. 11.

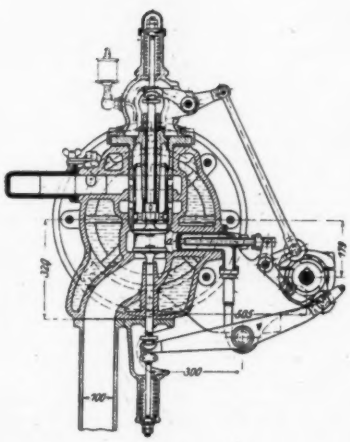

FIG. 13.

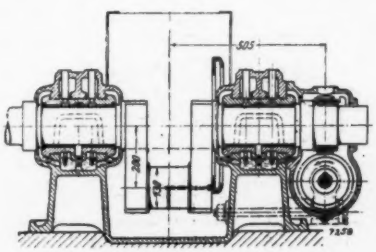

FIG. 15.

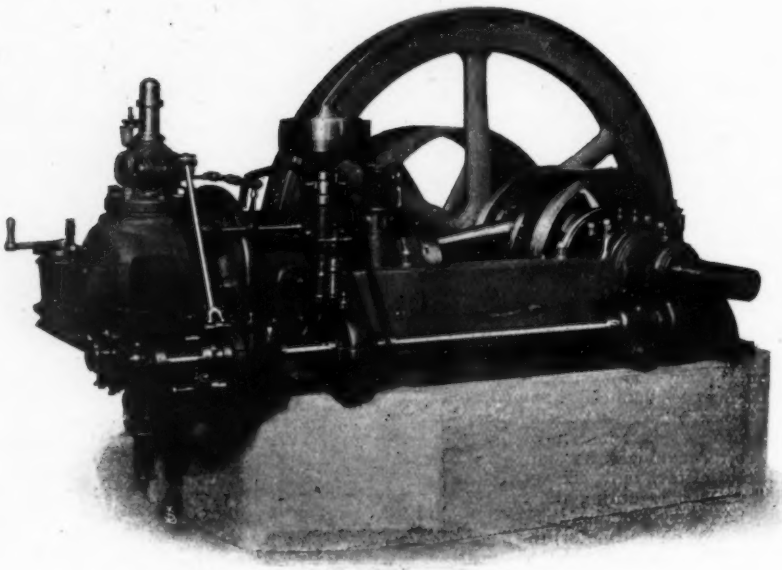

FIG. 16.—VIEW OF A "MEES" GAS ENGINE.

measure. As the ratio of cross-sections of the open channels, *m* and *i*, is kept constant for all positions intermediate between *II* and *III*, the composition of the mixture will, throughout this path, also remain the same as in position *II*. The latter position with which the transition occurs from mixture to charge regulation, should obviously be so designed that the mixture drawn in is still strong enough to warrant a safe ignition and lively explosion. The mixture and charge regulation of a motor can, however, be obtained also by giving the channels another shape. As shown in Figs. 5 to 7, the air channels, *i*, of the slide, *K*, may be designed of the same length as the gas channels, *m*, while having a combined triangular and rectangular shape, whereas the air and gas channels, *i* and *m*, in the slide box, *B*, as well as the gas channels, *ml*, in the slide, *K*, are given a rectangular shape. With channels of this form the transition from mixture regulation to charge regulation will not occur suddenly at a given point, but take place gradually. Other shapes of the channels will give similar results. The same effect can finally be obtained by means of a slide moved by the governor, as well as by a convenient valve regulation.

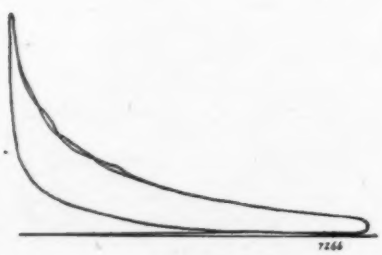

FIG. 17.

The effect of the new regulation process is represented in Figs. 8 and 9 for two different types of rotary slides, viz., in Fig. 8 for air and gas channels of different lengths, and in Fig. 9 for channels of different shapes.

In Figs. 10 to 15, a horizontal suction gas motor of a normal output of 21·5 h.-p. with regulation according to the novel process has been represented. The cooling jacket of the cylinder is cast from the same piece as the frame, while the cylinder, made from an especially hard and dense

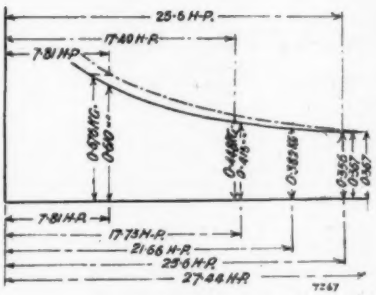

FIG. 18.

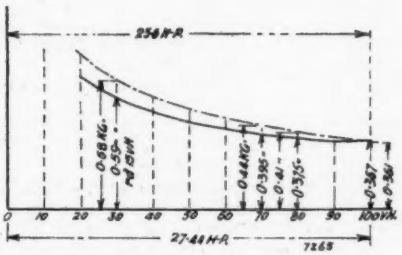

FIG. 19.

iron, can be readily exchanged. The crank shaft is supported by an external bearing resting on a special foundation and dealing with part of the weight of the flywheel. The magneto-electric ignition device has been so designed that the moment of ignition can be displaced during operation. The engine is started by means of compressed air, obtained by a small compressor driven from the transmission shaft and which is accumulated in a reservoir of suitable capacity.

Efficiency tests made on an experimental engine of 20 to 22 e.h.-p. normal output have been continued for 9 hours each. The results may be said to be rather satisfactory, and to bear out fully any advantages claimed in the above for the new method of regulation. For an output of the motor of 21·66 e.h.-p. in two tests of 9 hours each, the consumption of English anthracite (of 7889 calories per kg. heating value) has for instance been found to be as an average only ·382 kgs. for each e.h.-p. hour.

Experiments were also made with two slides, having channels of different shapes, corresponding to a charge and combined regulation respectively.

The results of these experiments are shown in the diagrams of Figs. 17 and 18, where the curves drawn in full relate to the combined regulation and the dotted lines to the charge regulation. The diagram in Fig. 18. indicates the consumption of fuel found in connection with the two regulation methods as reduced to the same percentage of maximum power of the motor, the latter being different in the two cases (viz. 25·6 h.-p. in connection with charge regulation and 27·44 h.-p. in connection with the combined regulation). Fig. 18 thus allows of a direct comparison between the results obtained from the two regulation methods.

The economical advantage of the former process of regulation and the approximate constancy of the consumption of fuel within wide limits of the load will be readily inferred from the diagrams. Fig. 19 shows an indicator diagram recorded with the load of 25·6 e.h.-p.

A more recent design of the same engine has given even much more favourable figures, viz., about ½ kg. per e.h.-p. for different kinds of anthracite, this corresponding to about 75 per cent. of the maximum load.

Results of Recent Experience in the Bacterial Treatment of Sewage.—II.

By W. H. MAXWELL, A.M.Inst.C.E.

Crude sewage upon coarse beds.—Experiments have been made in the treatment of crude sewage upon coarse bacteria beds, dispensing altogether with the preliminary preparation afforded by the septic tank, and experience in this connection has been gained at Sutton, Manchester, Leeds, Hampton, and elsewhere. The first of such "coarse beds" was laid down at Sutton, Surrey, in the year 1896, but its use in that particular way has now been departed from, and the sewage is now settled in detritus tanks before being put upon the beds. These tanks are constructed as "septic" tanks, with submerged inlets and outlets, but their capacity is only about one-fifth of the dry weather flow, and the septic action is probably not carried very far. It is found sufficient, however, for the purpose, and prevents the choking of coarse beds and the reduction of their capacity, as is the case when crude sewage is placed thereon. The use of crude sewage results in the rapid choking and reduction of capacity of the beds, and long periods of rest are required even to partially restore their capacity. It is, however, difficult to lay down hard and fast rules applicable to every case, as everything depends upon the class of sewage to be treated, and for this reason it is generally advisable to introduce the bacterial system in the first instance on experimental lines, so that the experience thus gained as to the character and requirements of the sewage may form the basis upon which the larger works may be designed.

Suspended matter in effluents.—Comparison has been frequently made between the amount of suspended matter contained in a chemically precipitated effluent and that from the septic tank as a preliminary to filtration. It is well known that chemical precipitation may be made very efficient in the throwing down of suspended solids. By employing sufficiently heavy charges of precipitants, as at Kingston-on-Thames, a tank effluent is obtainable containing no more than from 1 to 2 parts of suspended matter per 100,000. For a precipitation effluent up to, say, 5 parts per 100,000 may be regarded as a low figure, but the amount will increase rapidly where chemicals are used sparingly or the tanks not well attended to. At Leeds the effluent from lime precipitation contains about 14·3 parts per 100,000 of suspended solids, and at Birmingham the amount in a precipitation effluent is given at 16·3 parts per 100,000 as against 24·5 parts from the septic tanks holding only 8 hours flow. Regarded as a preliminary to filtration, the suspended solids contained in the septic effluent, however, have the advantage of being of a less clogging nature than those from the chemical precipitation tank; they pass on to the filter in a finely divided state, and do not retain the water to the same extent.

At Leeds the effluent from an open septic tank contained 13·1 grains per gallon of suspended solids as an average of eighteen analyses as compared with 44·4 grains in the crude sewage.

Very satisfactory septic tank effluents as regards suspended solids were obtained in connection with the Hanley experiments as carried out by Dr. Reid and Messrs. Willcox and Raikes, of Birmingham, in which the average of seven sets of analyses show the suspended solids to be 4·4 parts per 100,000, from a sewage containing 62.9*, and it was considered that still better results would have been obtained by a more regular emptying of the detritus tank preceding the septic tank.

Sewage sludge.—One very important factor in favour of the septic tank in the preliminary treatment of sewage is the reduction of the quantity of sludge to be dealt with. The disposal of the precipitated sludge in all systems of sewage treatment, and especially in chemical methods, has always proved a matter of great difficulty and heavy expense where the quantity of sewage is at all considerable.

The usual percentage of water in normal sludge as swept from a precipitation tank is 90 per cent., whilst sludge-cake as

* Report by the Staffordshire County Medical Officer of Health on Experimental Disposal Plant at Hanley (July, 1904), page 7.

delivered from sludge-pressing machinery contains a little over 50 per cent. of moisture. This may be brought down to about 12 per cent. by air-drying. The quantity of wet sludge produced will of course vary according to the sewage and chemicals used, but the average quantity yielded daily per 1,000 persons in eight towns where lime and sulphate of alumina were added to the sewage was ·92 tons. At 30 gallons of sewage per head per day, this represents about 30 tons of wet sludge per 1,000,000 gallons. During the year 1901 an average of about 34·3 tons of sludge per 1,000,000 gallons were extracted from the sewage at the Barking outfall works of the London County Council, and about 21·7 tons per 1,000,000 gallons at Crossness.

Of pressed sewage sludge-cake containing about 50 per cent. of moisture the average quantity produced will be about 8 tons per 1,000,000 gallons, and as one-half will be water the dry solids will represent about 4 tons per 1,000,000 gallons, or about 63 grains per gallon.

Reference has already been made to the utility of the septic tank in the reduction of these large quantities of sludge, but in the present connection the experience of Manchester and Leeds will be of practical value. The experience gained at Manchester showed a digestion of about 57 per cent. of the solid matter entering the septic tank. On this point Dr. G. J. Fowler says*, "The total amount of sludge from the septic tanks during the year works out at an average of 6 tons per 1,000,000 gallons of sewage passing through the tanks as compared with 14½ tons, which is the average amount of sludge per 1,000,000 gallons obtained by chemical treatment during the previous four years. In making this comparison, the increased density of septic sludge must, of course, be taken into account, the average being about 85 per cent. water, as against about 88 per cent. in the case of sludge from chemical treatment. While there can be no doubt, therefore, by the use of septic tanks the amount of sludge to be dealt with as such is reduced, the determination of the amount actually disappearing by septic action is a matter of considerable difficulty." If the tanks had not been cleared the actual digestion of sludge would doubtless have been greater than represented by the foregoing figures, having regard to the fact that a considerable portion of sludge was removed, more on account of convenience than from any real necessity.

* "Recent Experience in the treatment of Manchester Sewage" (Glasgow, 1904).

Effluents from septic tanks.—At the present juncture it will be well to note the advantages of a septic tank effluent for subsequent filtration over that obtained from a chemical process. Experience goes to show that the work done in the septic tank goes beyond the mere removal of suspended solid matter, and that the tank effluent, if not too septic, is better prepared for the final state of purification and nitrification on the bacteria-beds. An interesting experience was gained at Oldham, where the sewage works were started as a precipitation works, using lime and copperas. The suspended solids were thus separated, but the dissolved impurities remained in the effluent. Bacteria beds were subsequently introduced to further deal with the chemically clarified liquid. A good effluent, coming below the standard required, resulted, but it was found after a time that equally good effluents could be obtained without the use of the precipitants, and these were accordingly abandoned.

Whilst there may be cases where the special nature of the sewage, as the result of trade refuse or other causes, renders the use of chemicals necessary, the great majority of sewages can be best treated bacterially without their use—the chemicals actually retarding the proper development of the bacterial processes.

The "cultivation tank" and nitrifying trays (Scott-Moncrieff).—Before leaving the subject of the septic tank as a preliminary bacterial process some reference is needed to the variation in principle adopted by Mr. Scott-Moncrieff in the installations put down upon this plan. Instead of an empty tank, as is the ordinary septic tank, Mr. Moncrieff uses what may be roughly described as a tank full of flints—the object being to provide anchorages or surfaces for the cultivation of colonies of anaërobic bacteria throughout the mass of the liquid. In this "cultivation tank" the sewage enters at the bottom, and passes upwards through a body of large stones carried on a grating, and escapes through an overflow at the top, at nearly the same level as the intake. The effluent from the tank is then distributed by means of tipping-troughs or distributors over the uppermost of a series of nitrifying trays or boxes with perforated bottoms and filled with coke about the size of beans. Importance is attached to the zonal character of the bacterial action, and it is contended that the zones, as the succession of the various layers, facilitate the different stages of decomposition, each having organisms best capable of carrying on the work of purification. The system

was first tried on a practical scale at Ashtead (1891), and has been adopted at the Caterham barracks and many other places at home and abroad.

The advantage of separating the organisms was borne out by the Massachusetts experiments, and the report of 1890 states that "in the filter-tanks at the Lawrence experiment station speedy nitrification was always co-incident with a marked decline in the numbers of bacteria. The more complete the nitrification the fewer were the bacteria in the effluent." In the Moncrieft nitrifying trays the nitrifying organisms are practically alone, and a high nitrification is obtained.

From an engineering standpoint the cultivation tank has the advantage, which is also shared by the septic tank, that little or no fall is absorbed in its construction, the inlet and outlet being very much on one level, but a point of much practical importance arises in connection with the provision of a "cultivation tank" for large volumes of sewage flow, inasmuch as it is obviously cheaper to provide a given capacity in a clear tank than in the interstices of materials such as flints filled into the tank space, so that unless some very marked advantage accrues by the adoption of this principle the question of comparative initial outlay is likely to be a determining factor in favour of the septic tank, at any rate for large volumes such as the sewage of a town. Also, the undigested matter is more readily and cheaply removed from the ordinary septic tank than from a cultivation tank, from which the materials may sooner or later require removal.

The stages of the complete system, however, appear to follow a well-thought-out scientific sequence and well provides for the separation of the anaërobic from the aërobic organisms employed in bringing about the desired liquefaction of the sewage and a satisfactory nitrification of the final effluent.

Anaërobic, aërobic, and nitrifying stages of purification.— Emphasis has already been laid upon the necessity of paying due regard, in the design of bacterial works, to the different stages of the work of purification, and of providing, as far as possible, for the separation of the classes of organisms bringing about the changes effected. Dr. Rideal* has very appropriately considered these changes under four headings. The initial stage relates to the condition of the sewage when quite fresh as discharged into the public sewers, and embraces transient aërobic changes by the oxygen of the water-supply. From this stage the sewage passes on rapidly to the first stage of purification at the outfall consisting of anaërobic liquefaction and preparation by hydrolysis. Following upon this preliminary preparation is the second stage, or the semi-anaërobic breaking down of the intermediate dissolved bodies; and finally is reached the third stage, covering the complete aëration and nitrification of the effluent discharged.

In the final purification of sewage the main object sought is the oxidation of the ammonia and organic compounds resulting from the preceding stages, and the bacterial changes in the beds or filters are mainly those associated with the process known as *nitrification* and the subsequent oxidation of the organic matter. A large number of the micro-organisms found in sewage are capable, under suitable conditions, of bringing about this nitrification, and the works for the final stage of the treatment must therefore be such as will favour their rapid growth and activity. This part of the work is found to be most effectively done upon the bacterial bed in one or other of its various forms.

Such a bed may consist of land of a naturally porous soil, or of land which has been specially prepared for the purpose, and may be worked and cropped in the usual manner. More commonly, however, specially built artificial beds or "filters" of clinker, coke, stone, or other material are employed.

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* "Sewage and Sewage Purification," by Dr. S. Rideal. The Sanitary Publishing Co.

(To be continued.)

The Prevention of Coast Erosion.—II.

By Dr. J. S. OWENS, B.A., A.M.Inst.C.E., F.R.G.S.

MATERIALS for use in the construction of sea defences should be selected with the greatest care. Durability and high specific gravity are the two principal qualities to be sought for.

Durability is affected by ordinary decay, erosion by moving sand and shingle, chemical action and exposure to changes of temperature, as well as by the direct attack of the sea itself and by the destructive action of sea-worms. In some localities floating ice is a serious danger to sea defences, as on the shores of the great American lakes; but, fortunately for us, it is a danger from which we are exempt in our warmer climate.

For the purpose of sea defence, we have been practically limited in this country, to three materials, until quite recently: masonry, concrete, and timber. Now, however, the introduction of reinforced concrete has placed a new material at our disposal, and one possessing, for this purpose, many advantages over the older materials. Masonry alone is now very seldom used in sea defence work, its sphere of usefulness being practically limited to facing concrete mass work. The resistance of hard stone, such as granite and basalt, to abrasion from the impact of pebbles and stones, makes it very useful when a specially hard, durable face is called for. The several kinds of granite and syenite are by far the most useful for such work; they have a fairly high specific gravity, are sufficiently hard to offer great resistance to erosion, and they can be readily cut and dressed. The weight of a cubic foot of granite varies from 165 lbs. in the Aberdeen grey variety, to 185 lbs. in the Guernsey stone. Basalt and like rocks are very suitable for some forms of sea work, owing to their very high specific gravity and great hardness. Some varieties of basalt, however, disintegrate rapidly under the influence of the weather; great care is therefore necessary in selecting a suitable kind. In basalt faced work it is not possible to obtain as close joints as can be made with properly dressed granite, and this is a point of some importance, in a structure exposed to the stroke of heavy waves.

The effect of the sudden propagation of the impulse, due to the stroke of waves acting through and within open joints or fissures in dislodging stones or breaking concrete, has often been noticed. An example of this, of a curious character, was observed by Mr. Mallet on the sea-walls of the Dublin and Kingstown Railway.*

During a severe storm from the E.N.E., at the time of spring tides, when the usual rise at Dublin, 12 ft., was increased to 17 ft., and when the heavy waves beat in, broadside on, upon long reaches of this wall, much of the capping of the parapet was dislodged, and vast masses of water rose like cascades and fell heavily upon the pavement inside.

> "The effect was, that many of the square granite blocks were seen by Mr. Mallet to jump out of their beds, at the instant of the fall of the sea upon them, and were thrown landwards towards the line of way."

This phenomenon appeared to him strange and inexplicable at first, as the blocks moved in apparently direct opposition to the force applied; but, he goes on to say—

> "The explanation was obvious. The force or impact of any sea striking on the top of the block, was propagated downwards, through the open lateral joints, and beneath the base, or bed of the stone."

The propagation of fluid impulse in this way was shown accidentally in a curious way, during the progress of experiments made by the French artillery at Metz, to ascertain the penetration of bullets in water:†

> "A long, rectangular, open-topped trough, about 12 in. in width, the same in depth, and say 20 ft. long, was formed of wood; one end being of indiarubber cloth. It was filled with water, and a common musket bullet fired, horizontally, into the water, through the indiarubber end. To the surprise of all, the trough was split to pieces, both the sides and the ends being thrown asunder."

One of the greatest advantages which concrete possesses over masonry for sea

* Proc. Inst. C.E., Vol. xviii., pp. 113—114.
† Proc. Inst. C.E., Vol. xviii., p. 114.

work lies in the possibility of obtaining homogeneity in the work, and reducing to a minimum the number of joints. Joints are always a source of weakness.

Concrete in England is nearly always composed of a mixture of Portland cement, sand and stone. Italian and French engineers, on the other hand, still use hydraulic lime for making concrete for sea work, whereas it is seldom used in England except in dock works.

In selecting the materials for making concrete, great care should be exercised. The ballast, or sand and stone, should be as hard and heavy as possible, and free from earthy or soluble matter.

They should be thoroughly mixed with the cement in a dry state, and again after adding the water. Concrete for sea work should be moderately wet, as it is of the first importance that the mass when set should not be porous. Sea water, percolating through the interstices of porous concrete has a tendency to cause disintegration, by dissolving out the calcium and depositing a salt of magnesium. It is unnecessary to dwell upon the properties of a good cement, as these are now well known, and specifications will be found in many of the text books.

Passing on to the consideration of timber for sea defences, it may be well to devote a little space to some of the enemies of timber work used for this purpose.

All woods are subject to the attack of marine animals, known usually as "sea-worms," but some are more liable to attack than others, and the value of any wood for use in marine work depends greatly upon its ability to resist injury or destruction by these animals.

The most important of the marine worms and insects which attack wood are the *Teredo*, the *Limnoria terebrans* and the *Chelura terebrans*. There are various species of *Teredo*, the best known of which is the *Teredo navalis*. It is very destructive to wood and is found in all British waters. It appears to prefer clear salt water and, to some extent, to avoid fresh, sewage polluted, and muddy water. The *Teredo* bores holes from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. in diameter and grows to a length of two or three feet. The burrows are usually driven in the direction of the grain of the wood, except when an obstacle is encountered, in the shape of a knot or the tube of an adjoining worm, in which case the course of the burrow is altered so as to pass round the obstruction.

The *Limnoria terebrans*, another destructive wood borer, is thus well described* by Professor Snow of New York University—

"It is much smaller and different to the *Teredo*, and wherever found is in large quantities. In temperate waters the *Limnoria* is about the size of a grain of rice, in cold water smaller, and in warm water attains the size of a pea. The body is greyish in colour, much resembles the common wood louse or sow-bug, can creep, swim backward and forward, as well as jump backward by means of its tail, and when touched draws itself up into a ball as the wood louse does."

The *Limnoria* prefers wet wood, which it attacks by means of its claws and mandibles, making a very clean cut burrow with parallel sides. It does not, however, burrow deeply into the wood, like the *Teredo*, but confines its efforts to near the surface, working to a depth of perhaps an inch. The workings are close together and weaken the wood so as to render it unable to resist decay or erosion by the waves. A new surface is thus exposed and attacked in its turn by the *Limnoria*, and so the timber is eventually destroyed, being eaten away from the surface.

This insect appears to be indifferent to the foulness of the water provided it be saline. It confines its ravages to the range of the tide. In this respect it differs somewhat from the *Teredo*, which commences its work about two or three feet above ordinary spring tide and three or four feet below low water.

The *Limnoria*, on the other hand, prefers to work about the level of high water neap tides.

The *Chelura terebrans* is a shrimp which works beneath the surface of wood, separating off flakes which fall away. It prefers pure sea water, and is therefore more often found on the open coast than in enclosed harbours.

There are many other insects which attack wood, but these are by far the most important in this country. The problem of protecting timber sea defences from their ravages is one of the most serious which we have to deal with.

Many methods have been tried to cope with this difficulty. Metallic sheeting of either copper or zinc has been used with some success. Copper sheeting gives a very satisfactory protection but is very costly; a zinc covering is soon corroded away by the action of the sea water.

"Teredo" nails are used much in Holland and are fairly satisfactory. They are flat-headed iron nails driven close together; on

* Paper read before the American Society of Civil Engineers.

rusting they form an impervious skin over the surface of the piles.

Creosoting is the most successful method of dealing with these borers in timber work, and is very widely adopted in this country. It has, however, the serious drawback that the timber which takes creosote best is soft and unsuitable for bearing heavy stresses, whereas heavy timber of close hard grain, such as oak, does not absorb enough creosote to protect itself.

It is of great importance in creosoting timber that it should be cut to its final dimensions before being impregnated, since the greater part of the oil is contained in the surface layers of the wood, and new surfaces exposed by cutting away the timber after creosoting afford an easy entrance to wood-boring animals. For sea work 10 to 12 lbs. of creosote per cubic foot will afford sufficient protection in these latitudes.

Timber suffers also from the defect of buoyancy when used in sea defences. Unless very firmly fixed in position the water will float it away. The alternate exposure to water and air also tends to produce decay; and when kept constantly soaked with water, timber loses some of its strength and is easier broken than when dry.

The accompanying table gives some of the properties of the commoner woods which have a bearing upon their value for sea defence. The transverse strength given in the table is the breaking weight of a beam 1 in. wide, 1 in. deep, and 1 ft. clear span with a concentrated central load.

After a careful consideration of the materials mentioned, it will be seen that all have drawbacks as well as advantages. When the necessary conditions which a material for sea defences should fulfil are kept in view, it must be admitted that none so nearly fulfils these conditions as the new reinforced or "ferro" concrete. This is especially so if we limit our attention to groynes. Here we have a material combining in itself the advantages of iron, concrete and timber. The specific gravity is high, it is not liable to be destroyed by the "worm," and instead of decaying like timber or rusting like iron it grows stronger with age. The cost compares favourably with timber. It is found also that the concrete affords a perfect protection for the iron embedded in it. In properly made concrete which is not porous, the surface of the iron becomes coated with a silicate, which helps to protect it from rust.

In view of the many advantages of reinforced concrete over other materials for this work, I have devoted some time to the design of a groyne suitable for foreshore protection and constructed entirely of this material. A description of this groyne will be given further on.

PROPERTIES OF TIMBER.

Timber.	Average Specific Gravity.	Weight per cubic foot in lbs.	Estimated durability in Years.	Transverse strength in lbs.	Amount of Creosote absorbed per Cubic Foot in lbs.
Elm (English)	0·553	34	5	350 to 450	13
Birch	0·69	43	5	550 to 700	8 to 16, but very variable.
Oak (English)	0·777	48	12	500 to 650	3 to 6
Pitchpine	0·675	42	7	500 to 700	Average 3½ to 4 but variable.
Larch	0·53	32·5	7	—	6 to 11½
Pine (Red)	0·576	36	5	350 to 500	6 to 12
Oregon Pine	0·55	34·3	—	—	3½ to 4
Spruce Fir	0·512	32	5	400 to 500	9 to 10, very variable.
Greenheart	1·143	71	12	900 to 1500	—
American Rock Elm...	0·725	45	6	—	2
Jarra	1·01	63 to 64	—	500 to 650	—
Karri	1·12	63 to 64	—	650 to 850	—

The durability as given in column 4 is as estimated for shipbuilding purposes by a committee of Lloyd's. The strength in column 5 is taken from "Dock Engineering," by B. Cunningham, and is the concentrated central breaking weight of a beam 1 in. by 1 in. by 1 ft. clear span. The column showing creosote absorbed per foot cube, is prepared chiefly from particulars of experiments supplied to me by Messrs. Burt, Boulton and Haywood. The figures must be taken as giving average absorption, as they inform me that "different pieces of timber behave so erratically that one cannot dogmatise." This erratic behaviour appears specially marked in the case of Birch, Pitchpine and Spruce. The figures do not apply to the behaviour of small blocks, such as used for paving, which take the creosote in large quantity through the end grain.

(To be continued.)

Superheated Steam.

By MICHAEL LONGRIDGE, M.Inst.C.E., M.I.Mech.E.

THE properties of superheated steam formed the subject of an exhaustive article that appeared in the last issue of THE ENGINEERING REVIEW. That contribution, however, was limited in its scope to a consideration of the methods employed and the results reached in the endeavour to accurately determine the specific heat of superheated steam. There is, however, a further and perhaps more interesting aspect of superheating, namely, how it is that its adoption improves the economy of the steam engine. To a consideration of this point and to the principles on which a superheating plant should be designed, the author applied himself in an interesting lecture recently delivered before the Bradford Engineering Society at the Bradford Technical School.

The choice of this particular subject was stated to be determined by two reasons: first, because it is uppermost in the minds of many engine-makers and steam users; and secondly, because many people appear to hold strange and erroneous opinions about its properties and uses. Some associate superheated steam with enormous pressures and explosive tendencies, and therefore regard its use as being attended with danger, while others, proceeding to the opposite extreme, would extend its application to purposes for which it is quite unsuitable. The lecturer proceeded to a description of the physical properties of steam.

Suppose we have a vertical cylinder, open at the top, containing a frictionless and weightless piston of 1 sq. ft. area, capable of being loaded by weights to exert any desired pressure upon the fluid under it. Suppose we put 1 lb. of water under it and apply heat through the bottom of the cylinder, we shall observe the following changes in the state of the water:—

First, its temperature will increase, but the piston will remain stationary (save for a very small rise due to the expansion of the water). The temperature will continue to rise till the boiling-point is reached. If at any time during this period we draw away heat through the cylinder bottom, the temperature of the water will fall, but its volume will remain practically unchanged.

Second, if after the boiling-point has been reached we continue to add heat, steam will be generated, and the piston will be forced upwards; but till all the water is evaporated the temperature will remain unchanged. If we withdraw heat from the steam, some of it will return to the state of water; but until all has been condensed the temperature will remain unchanged. Steam in this condition is known as dry saturated steam: dry because it contains no water, saturated because the abstraction of the smallest quantity of heat reduces some of it to water. Dry saturated steam mixed with varying quantities of water is the kind of steam supplied by ordinary steam boilers.

If, after all the water has been evaporated, and the cylinder filled with dry steam, we add still more heat, the temperature of the steam will rise, and its volume will increase; but the pressure will remain unchanged, and equal to the load upon the piston. The steam will become superheated, and will behave approximately like a permanent gas. If heat be extracted from it, the temperature will fall, and its volume will decrease; but there will be no condensation till the temperature has fallen to that at which the water began to boil, or, in other words, until the steam has returned to a state of saturation.

The boiling temperature of water varies with the pressure under which evaporation takes place. For every pressure there is a fixed unchangeable temperature at which water begins to boil, and this is always the temperature of the saturated steam at the same pressure. It is therefore impossible to increase the temperature of saturated steam without at the same time increasing its pressure.

The temperature of superheated steam is independent of the pressure, and may be increased to any extent without increase of pressure.

The temperatures, the quantity of heat contained in 1 lb. weight, and the volume

of 1 lb. weight of dry saturated steam at various pressures up to 400 lb. per sq. in., were determined by Regnault, in Paris, about sixty years ago, and are to be found in the steam-tables printed in most engineers' pocket-books and elsewhere. I give the figures for steam at atmospheric pressue and at 100 lb. and 160 lb. gauge pressure—*i.e.*, at absolute pressures of 14·7 lb., 114·7 lb., and 174·7 lb. per sq. in.

Gauge Pressure.	Absolute Pressure.	Boiling Temperature and Temperature of Steam.	Heat Required to Raise 1 lb. of Water from 32° to Boiling Temperature.	Heat Required to Evaporate 1 lb. of Water at Boiling Temperature.	Total Heat Required to Turn 1 lb. of Water at 32° into Steam.	Volume of 1 lb. of Steam.
lb. per sq. in.	lb. per sq. in.	Deg. Fahr.	B. T. U.	B.T.U	B.T.U.	cu. ft.
0	14·7	212	180	966	1146	26·34
100	114·7	338	308	876	1184	3·8
160	174·7	371	341	853	1194	2·56

The letters B.T.U., used above, signify British thermal unit—a unit of heat being the quantity of heat required to raise the temperature of 1 lb. of water fron 32° to 33° Fahr., or approximately to raise the temperature of 1 lb. of water at any temperature 1° Fahr. From such tables steam-users may learn all they need know about the physical properties of saturated steam.

The quantity of heat required to raise the temperature of 1 lb. of superheated steam 1° Fahr. is not accurately known.

Experiments have been made in England, America, and Germany, with very discordant results. Various values, ranging from 0·48, the figure usually given in the text-books, up to 0·75 have been put forward. I think, on the whole, we may for the present, at all events, assume that the specific heat of superheated steam increases with the pressure, and decreases with the temperature, some such figure as the following being probably nearer the true value than the constant 0·48, usually given.

I said that superheated steam behaved like a permanent gas. As regards expansion, this is only true when the temperature is considerably above the saturation temperature. For low degrees of superheat the expansion is more rapid than that of a gas, owing, no doubt, to the evaporation of very minute vesicles of water suspended in the steam. This may also account to some extent for increase of specific heat at low

Absolute Pressure.	Temperature of Saturated Steam.	Specific Heats of Superheated Steam at Undermentioned Temperatures.			
		400° Fahr.	500° Fahr.	600° Fahr.	700° Fahr.
lb. per sq. in.	Deg. Fahr.				
60	293	0·55	0·50	0·49	0·48
90	320	0·6	0·51	0·48	0·48
120	341	0·63	0·55	0·48	0·48
150	358	0·72	0·63	0·35	0·48

These figures are taken from a diagram published by Professor Smith in *The Engineer*, July 8, 1904.

temperatures. At higher temperatures the increase of volume due to increase of temperature is probably the same as in the case of a gas—that is to say, a volume of V cubic feet at temperature t_0 Fahr. becomes $V \times \frac{461 + t_1}{461 + t_0}$ when raised to a temperature of t_1 Fahr.

The physical properties of superheated steam are now being investigated by Dr. Glazebrook at the National Physical Laboratory.

Superheated steam is used for various purposes, but I propose to deal only with its application to steam-engines as a means of improving their economy. The best steam-engines I know of yield only about 70 per cent. of the work due from the steam supplied to them, and the majority even of good engines far less. The causes of this loss of efficiency are warmly disputed by professors and engineers. There are two theories: one, identified with the name of Adolf Hirn, attributes it to condensation in the cylinder; the other, put forward more recently by Messrs. Callender and Nicholson, ascribes it for the most part to leakage past valves and pistons. I am not going to dogmatise upon so difficult a question, nor is it necessary that I should do so, because I think I can show you that in either case superheating is in a greater or less degree a benefit to the steam user.

Hirn's view being the older in point of time, we will consider it first. Hirn held that the surfaces of the cylinder and piston absorbed heat with great rapidity from saturated steam or water hotter than themselves, and gave up heat with equal rapidity to steam or water cooler than themselves, and therefore that when hot steam from the boiler was admitted to a cylinder cooled by contact with lower temperature steam during the previous exhaust stroke, it parted with some of its heat to the metal; and when the exhaust port opened, this heat, which had been lying hidden away in the

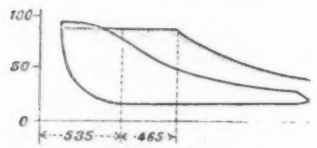


FIG. 1.—LOAD, 220; DEGREES OF SUPERHEAT, 0; STEAM PER I.H.-P. HOUR, 39·625.

metal, was poured out into the exhaust pipe, and thus passed through the cylinder without doing its fair share of work.

Referring to Fig. 1. It is taken from Professor Ripper's paper on "Superheated Steam," read before the Institution of Civil Engineers in January, 1897, vol. lxxviii. On it are two indicator diagrams: the smaller one, the diagram actually drawn by the indicator when the engine was working with saturated steam; the larger one, the saturation curve, or, approximately, the diagram which would have been drawn if all the steam admitted to the cylinder had existed as steam at the end of the admission.

A comparison of the two diagrams shows that the "missing quantity" amounted to no less than 46·5 per cent. of the steam admitted to the cylinder. The existence of this missing quantity, whenever saturated steam is used, is ascribed by Hirn's followers to condensation of the entering steam produced by absorption of heat by the metallic surfaces cooled by the previous exhaust stroke.

Perhaps the calculation of the loss by condensation in an imaginary case of a very simple character may make the action of the metal clearer. Suppose we assume that our cylinder and piston (Fig. 2) are made of cast iron $\frac{1}{64}$ in. thick, and therefore that the cylinder bottom and piston together weigh 1·17 lb., and the cylinder barrel 2·06 lb. per foot of height, and that the piston is loaded to exert a pressure of 115 lb. per sq. in. upon the fluid beneath it. If the cylinder exhausts into the atmosphere, the steam will leave it at a temperature of 212°. Suppose the metal to be at that temperature when we admit 1 lb. of dry saturated steam at 100 lb. gauge pressure below the piston. If no condensation took place, the piston would rise to a height of 3·8 ft. above the bottom of the cylinder, because the volume of 1 lb. of dry saturated steam at 100 lb. gauge pressure is 3·8 cubic feet, and the area of the piston is 1 sq. ft. The work done in lifting 16,550 lb. a height of 3·8 ft. would be 144 × 115 × 3·8 = 63,000 foot-pounds. But since the temperature of the entering steam is 338°, and the temperature of the metal only 212°, it is quite clear that heat will pass from the steam to the metal until the latter has also attained a temperature of 338°; for the temperature of saturated steam is not reduced by taking heat from it.

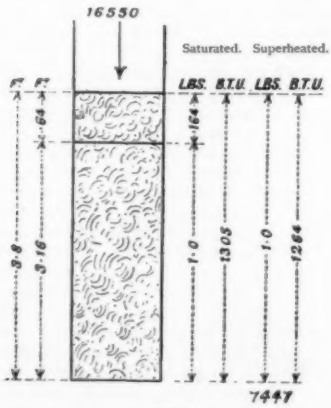


FIG. 2.

Now the quantity of heat required to raise the temperature of 9 lb. of cast iron (which is the weight of the piston, cylinder, and 3·8 ft. of the cylinder barrel) from 212° to 338° is (338—212) × ·13 × 9 = 147 B.T.U. This heat, then, must be taken from the steam. But, as you have already learnt, heat cannot be taken from saturated steam without condensing it. Therefore the effect of abstracting 147 B. T. U. from the steam in the cylinder is to condense a portion of it. The exact quantity is easily arrived at. The short steam table given above shows that the abstraction of 876 B. T. U. from 1 lb. of saturated steam at 100 lb. gauge pressure will reduce the whole to water.

Therefore, the abstraction of 147 B. T. U. from the pound of steam in our cylinder will reduce $1 \times \frac{147}{876} = 0{\cdot}168$ lb. to water. This will be the "missing quantity." In consequence of the condensation there will only be 1 - 0·168 lb. = 0·832 lb. of steam left as steam in the cylinder at the end of the admission, and as the volume of 0·832 lb. of steam at 100 lb. guage pressure is 0·832 × 3·3 = 3·16 cubic feet, the piston, instead of travelling at 3·8 ft., will only travel at 3·16 ft., and instead of getting 63,000 foot-pounds of work out of our pound of steam, we only get 52,400 foot-pounds.

Before the piston can rise to 3·8 ft. the

missing quantity of 0·168 lb. must be supplied out of the boiler, and, therefore, 1·168 lb. of steam must be expended to do the work which 1 lb. would have done had there been no cylinder condensation. The condensation has increased the steam consumption by 17 per cent. If the steam be now permitted to escape into the atmosphere, its pressure will fall to that of the atmosphere, and its temperature to 212°. The metal will then be the hotter body, and the heat absorbed by it during the admission will flow back to the steam and water or dew in contact with it until its temperature returns to what it was at the beginning of the experiment—viz., 212°.

I have made this calculation merely to give a round idea of the general nature of the action of the cylinder metal upon the steam during the admission period, and not as any indication of its magnitude.

For in the cylinder of a steam engine the conditions are quite different from those assumed. The metal surfaces are not exposed only to the admission and exhaust temperatures, but to all intermediate temperatures, and to each temperature, for variable periods of time. Moreover, even in the slowest running engines, the time between successive admissions and exhausts is too short to allow the change of temperature to extend right through the metal. The result is that in a well-clothed cylinder the greater part of the material remains at a constant temperature approximately half-way between the temperatures corresponding to the mean steam pressure and to the mean exhaust pressure. The variations of temperature in the metal induced by the variations of pressure and temperature of the steam extend only a short distance from the inner surface and diminish in amplitude as the distance from the surface and number of revolutions per minute increase. If we imagine the cylinder, (Fig. 3), made up of a number of concentric cylinders, each $\frac{1}{60}$ in. thick, then, if the temperatures of the entering steam and of the exhaust be 338° and 212°, and the mean temperature of the metal 250°, the temperature of the innermost ring will rise during the admission to some temperature Ta_1 greater than 250°, but less than 338°, and will fall during the exhaust to some temperature Te_1 less than 250°, but greater than 212°.

In the next ring the range of temperature $Ta_2 - Te_2$ will be less than $Ta_1 - Te_1$, and so on, until at some distance from the inner surface it will be reduced to zero, and Ta and Te will both become equal to the constant mean temperature of the metal

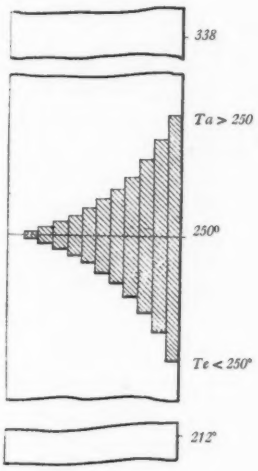


FIG. 3.

lying outside the zone affected by change of temperature.

If the areas of the shaded portion for all parts of the cylinder surface could be obtained by calculation, it would be possible to determine *a priori* the quantity of heat which would be absorbed and the magnitude of the missing quantity in any proposed steam-engine. So complicated, however, are the conditions affecting the heat exchanges that the problem has so far baffled engineers and physicists alike. I know of no reliable formula for finding these quantities, though several empirical expressions, based on a limited number of experiments, are in use (see, for instance, *Proceedings of the Institution of Mechanical Engineers*, May, 1892, page 199).

The fact that heat passes from the steam to the metal and from the metal to the steam, however, is beyond dispute. It has been demonstrated experimentally by Donkin and others, who, by means of delicate thermometers and thermo-couples, have measured, with more or less exactness, the changes of temperature at different distances from the surface of the metal. Fig. 4 is a copy of one of the late Mr. Donkin's diagrams showing the changes measured at a speed of 17½ admissions per minute with a steam temperature of 290° and an exhaust temperature of 173° Fahr. The original and other similar diagrams may be found in the Minutes of *Proceedings of the Institution of Civil Engineers*, vol. cxv., Plate VI. The diagram does not show the

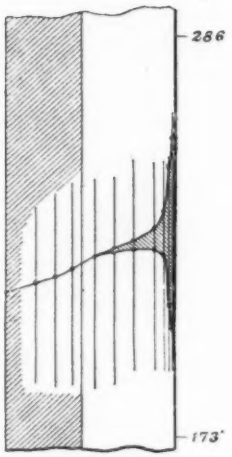


FIG. 4.

full extent of the temperature variations because the lag of the mercury thermometers used for measuring them damped the oscillation of the mercury. Still, it shows that they were considerable, and penetrated more than half-way through the metal, which was 1 in. thick.

How, then, does superheating reduce the loss, assuming it is to be due, as Hirn maintained, to cylinder condensation?

In the first place it enables the steam to carry into the cylinder sufficient heat to supply the demands of the metal without suffering condensation; for the effect of taking heat from the superheated steam is not to condense it, but to reduce its temperature.

Let us go back to our imaginary cylinder. We saw that when using saturated steam we had to supply 1·168 lb. of steam to lift the piston 3·8 ft., and that of this 0·168 lb. was condensed to supply the 147 B.T.U. required to raise the temperature of the metal from 212° to 338°. Now, assuming the specific heat of superheated steam to be 0·5, which means that half a unit of heat will raise the temperature of 1 lb. of superheated steam 1° Fahr., it appears that if we superheat the steam $147 \div 0{\cdot}5 = 294°$ Fahr. —*i.e.*, increase its temperature to 632°—we shall, without increasing its pressure, charge it with the 147 units required to supply the cylinder metal, and when the metal has absorbed them we shall still have 1 lb. of saturated steam at 100 lb. gauge pressure below the piston. Therefore the piston will be raised 3·8 ft., and the work which required 1·168 lb. of saturated steam will have been performed by 1 lb. of superheated steam at the same pressure.

The saving in steam due to superheating would therefore be

$$\frac{1{\cdot}168 - 1{\cdot}60}{1{\cdot}168} \times 100 = 14{\cdot}4 \text{ per cent.}$$

In making this statement I am telling you the truth, and nothing but the truth; but, unfortunately for the case of superheating, not the whole truth. I have not explicitly pointed out that 1 lb. of superheated steam costs more than 1 lb. of saturated steam, because it contains more heat. This fact should always be remembered when discussing savings due to superheat. The cost of superheating will vary with the pressure and degree of superheat. In the case we have been considering, the heat required to produce 1·168 lb. of saturated steam at 100 lb. gauge pressure from feed-water 100° is (see Table above),

$$1{\cdot}168 \times (1184 - 68) = 1{,}305 \text{ B.T.U.},$$

while the cost of producing 1 lb. of steam under the same conditions, and superheating it to 632°, is

$$1 \times (1116 + 0{\cdot}5 \times 294) = 1263 \text{ B.T.U.}$$

The saving in heat is therefore only

$$\frac{1305 - 1263}{1305} \times 100 = 3{\cdot}2 \text{ per cent.}$$

But, you will say, if this be all the saving to be made by superheating to 632°, the game is hardly worth the candle. My answer to the criticism is that the calculation was not made for the purpose of estimating savings, but of demonstrating how, by giving up superheat instead of latent heat, the steam might be made to supply the demands of the cylinder metal without condensing. In making it, as in making a similar calculation for saturated steam, we took no count of time, and assumed that the temperature of the whole mass of the metal followed that of the steam.

But we have already seen that, as regards the cylinders of steam-engines, the assumption is untrue, because the action of the metal on the steam, even when saturated, is limited by time. With superheated steam the limitation is far greater, because superheated steam is, like a gas, a bad conductor of heat. It gives up heat slowly to dry metallic surfaces, and the surfaces radiate heat or cold with difficulty through it. Consequently, in the time occupied by one

revolution the cylinder of a steam-engine absorbs far less heat when it is kept dry than when it is bathed in a fog of saturated steam and water. This is the secret of the economy of superheat: to reduce the missing quantity by keeping the cylinder dry, if not throughout the stroke, at least during the period of admission, when, with saturated steam, the largest proportion of the condensation is produced. To illustrate this statement I refer you to Fig. 5.

The diagram, of which the figure is a copy, was taken from the same engine as Fig. 1, driving the same load at the same speed and with the same steam pressure, but working with superheated steam. The original will be found in Professor Ripper's paper above referred to. A comparison with Fig. 1 shows that in this particular case superheating reduced the missing quantity to nothing, the steam consumption by $\frac{39{\cdot}62 - 20{\cdot}08}{39{\cdot}62} \times 100 = 49\frac{1}{2}$ per cent., and the heat consumption by $\frac{48{,}200 - 27{,}800}{48{,}200} \times 100 = 42\frac{1}{2}$ per cent. I say "in this particular case" because I do not wish you to go away with the idea that such enormous savings are to be generally expected.

Professor Ripper's engine was a small one, with two single-acting cylinders, each 7·094 in. in diameter by 11·8 in stroke, and in appearance something like two gas-engines placed side by side. In comparison with their internal surfaces, the cylinders had very little steam, and therefore the condensation and the missing quantity, when working with saturated steam, was much greater than in the large and more economical engines usually found in factories. It is in those engines that your interest lies, and the question you probably want me to answer is, What saving can be made by supplying superheated steam to them?

In the absence of any accurate formula for determining the magnitude of the missing quantity from the dimensions and working conditions of an engine, I fear it is impossible to give a definite and scientific answer; but in cases where the missing quantity is known a rough approximation to the probable saving may be made.

The figures given in Professor Ripper's paper seem to show that somewhere about 6° of superheat are required to reduce the missing quantity by 1 per cent. What I mean is, that if the dryness fraction at cut-off in any cylinder were 0·75, it would be increased to 0·85 by superheating $10 \times 6 = 60°$, and to 1 by superheating to

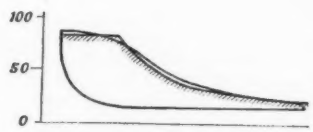


FIG. 5.—LOAD, 220; DEGREES OF SUPERHEAT, 320·8; STEAM PER I.H.-P. HOUR, 20·077.

$25 \times 6 = 150°$ Fahr. This proportion must not be taken as a law, for the experiments from which it is derived were limited in number, range of pressure, and expansion; but as a rough approximation it may, I think, be accepted.

If, then, we know the missing quantity in any case, we can form some idea of the superheat required to suppress it, and of the saving to be expected from its suppression.

For simplicity take the case of a cylinder receiving 1 lb. of saturated steam per stroke.

Let

- p_1 p_0 be the admission and exhaust pressures in pounds per square inch;
- v_1 the volume of 1 lb. of steam at pressure p in cubic feet;
- v_0 the total volume of the cylinder per lb. of steam;
- r the ratio of expansion;
- x the dryness fraction at the end of admission;
- n the number of degrees of superheat of the steam admitted to the cylinder;
- k the specific heat of superheated steam;
- H the total heat in 1 lb. of saturated steam at pressure p;
- t_0 the temperature of the feed;

then the volume occupied by the steam at the admission will be $x\ v_1$; and if we assume the expansion to be hyperbolic, as it is approximately with saturated steam, the value of r will be $\frac{v_0}{x\ v_1}$, and the mean effective pressure of the diagram would be

$$p_m = \frac{p_1}{r}\left\{1 + \log_e r\right\} - p_0.$$

The work done per pound of steam would therefore be

$$144\ p_1\ \frac{v_0}{r}\left\{1 + \log_e r\right\} - 144\ p_0\ v_0 \text{ foot-pounds.}$$

The heat expended in doing this work would be $(H - t_0)$ B.T.U.

Now suppose we superheat $x\ v_1$ pounds of steam 600 $(1-x)$ above the saturation temperature before admitting it to the

cylinder, thereby suppressing the missing quantity $(1-x)\ v_1$, we shall have at the end of the admission, when the steam has given up its superheat to the metal, $x\ v_1$ pounds of dry saturated steam in the cylinder. If the expansion were hyperbolic, the diagram, the mean effective pressure, and the work done would be as before, but the steam expended would have been $x\ v_1$ pounds and the heat $x\ v_1\ [H-t_0+600\ (1-x)\ k]$. The saving by superheating $600°\ (1-x)$ and suppressing the missing quantity would therefore be

In steam

$$\frac{1-x}{1} \times 100 \text{ per cent.}$$

In heat

$$\frac{H-t_0-x\ [H-t_0+600\ (1-x)\ k]}{H-t_0} \times 100.$$

The actual saving will be somewhat less, because the expansion curve, if the steam be dry at the end of the admission, will fall somewhat below the hyperbola, and lower still if it be superheated throughout the expansion. In either case the curve will be of the form $p\ v^n =$ constant. In this case the mean effective pressure will be

$$\frac{n}{n-1} \times \frac{p_1}{r_1} - \frac{1}{n-1} \times \frac{p_1}{r_1^n} - p_0.$$

Equating this to the mean pressure found from the saturated steam diagram, the values of r and $x\ v$ can be obtained, and from these the percentages of steam and heat saved by superheating. Assuming always that 6° of superheat will suppress 1 per cent. of initial condensation, and the more complicated cases in which the superheat is greater or less than $600\ (1-x)$ can be dealt with in a somewhat similar manner.

Probably the best plan in such cases would be to draw the diagrams instead of calculating the mean pressures. To do this, I think it may be assumed approximately that when superheat is less than $600\ (1-x)$ the expansion curve will tend towards the hyperbola and n towards unity.

When equal to $600\ (1-x)$ the curve will tend towards a saturation curve, and n will be about 1·063.

When greater than $600\ (1-x)$, so that the steam is superheated throughout the stroke, n will be about 1·18.

These formulæ will enable anyone to estimate roughly the superheat and probable saving in a single cylinder, whether it belong to a simple, compound, or triple-expansion engine. In dealing with a multiple cylinder engine as a whole, both superheat and saving will depend upon the way in which the superheat is applied. It is practically impossible to have superheat in any but the first cylinder of a multiple-cylinder engine unless the steam be reheated from cylinder to cylinder. For this reason triple and quadruple-expansion engines are unsuitable for superheated steam. We need, therefore, consider two cylinder engines only. If there be an intermediate receiver in which the exhaust from the smaller cylinder can be superheated before passing into the larger cylinder, then, if we know the dryness fraction (x^1) in the larger cylinder when working with saturated steam, we can calculate the superheat required for this cylinder.

This superheat may be supplied most economically by increasing the superheat of the steam supplied to the engine above that required for the high-pressure cylinder, and then transferring the exhaust from the high-pressure cylinder by passing the whole of the steam going from the boiler to the high-pressure cylinder through the tubes of a receiver, through the intertubular space of which the exhaust from the high-pressure cylinder passes on its way to the low-pressure cylinder. If t^{11}_x be the extra superheat required for superheating the steam admitted to the low-pressure cylinder, then $t^{11}_x = 600k\ (1-x^1)$, and the total heat to be supplied per pound of steam will be, roughly, $H-t_0+600k\ (1-x+1-x^1)$.

If, on the other hand, there be no receiver, then the saving will be effected in the high-pressure cylinder only. In this case it is evident that as large a proportion of the work as possible should be done in the high-pressure cylinder, and therefore that this cylinder should be as large as convenient compared with the low-pressure cylinder. The proportion between the two will depend upon the superheat available, because in any cylinder the missing quantity, and therefore the superheat required to suppress it, increases as the number of expansions in that cylinder.

Now, as far as I know, Corliss valves will work quite satisfactorily in a temperature of 500° Fahr., and piston and double-beat valves in a temperature of 600° or more. Working with steam of 140 lb. gauge pressure, which seems to me to be on the whole, the best pressure for a compound engine, these temperatures correspond to superheats of 139° and 239° respectively, and should be sufficient to suppress missing quantities amounting to $\frac{139 \times 100}{6} = 23$ per cent. and $\frac{239 \times 100}{6}$ $= 40$ per cent. respectively.

With saturated steam these percentages would probably correspond to about four and five expansions, or with clearances of 5 per cent. to admissions of 0·2775 and 0·16 of the stroke. With 140-lb. gauge pressure the total number of expansions through the engine should be about $\frac{140 + 15}{10} - 1 = 14{\cdot}5$, so that if v V c C be the piston displacements and clearance in the high-pressure and low pressure cylinders, we have in the first case

$$V + C = 14{\cdot}5\,\frac{v + c}{4},$$

and in the second

$$V + C = 14{\cdot}5\,\frac{v + c}{5}.$$

If the clearance be 5 per cent., then

$$V = 3{\cdot}6\ v \text{ in the first case,}$$

and

$$V = 2{\cdot}9\ v \text{ in the second.}$$

The conclusion arrived at in this argument unfortunately depends upon a knowledge of the missing quantity. Without a means of ascertaining it, they are useless. I have already said that I know of no accurate method of calculating it *a priori* from the cylinder dimensions and conditions of working; but there are now numerous published reports of engine trials in which it is given for the particular engines tested, and from these a fair idea may be obtained of the probable dryness fraction in ordinary cases.

I intended to have tabulated the figures from a number of these reports, but the lack of time has made the task impossible. You will have to do that part of the work yourselves.

We must now leave Hirn's theory of cylinder condensation and pass on to that of Messrs. Callender and Nicholson, which attributes the missing quantity principally to leakage past valves and pistons. I cannot go into their reasons or the evidence they have produced in support of their conclusions, but I should like to indicate as briefly as I possibly can why superheating should improve the economy of the steam-engine, if their theory be correct.

You all know that the velocity of flow of a fluid through an orifice is proportional to the square root of the head under which the discharge takes place. Also that the height of a column of fluid of 1 square foot base multiplied by the weight of 1 cubic foot of the fluid is equal to the pressure in pounds per square foot exerted on the base of the column. Let us consider two or three cases of the velocity of flow under a pressure of 115 lb. per sq. in. or 16,550 lb. per sq. ft. of

1. Dry saturated steam.
2. A mixture of 95 per cent. of dry saturated steam and 5 per cent. of water.
3. Of steam superheated 200°.

In the first case the weight of 1 cubic foot of dry saturated steam at 115 lbs. pressure is 0·2628 lb., therefore the head under which steam would flow through a hole of given size would be 16,550 ÷ 0·2628 ft. = 63,900 ft., and the velocity of flow would be $8 \times \sqrt{63{,}000} = 2008$ ft. per second.

In the second case, the weight of a cubic foot of the mixture of steam and water would be 0·278 lb.* The head equivalent to a pressure of 115 lb. per sq. in. would be 16,550 ÷ 0·278 = 59,600 ft., and the velocity due to the head 1952 ft. per second.

In the third case, the weight of one cubic foot of superheated steam at 538° temperature will be 0·21 lb.† The head equivalent to a pressure of 100 lb. per sq. in. would be 16,550 ÷ 0·21=78,900 ft., and the velocity due to this head would be 2444 ft. per second.

Now the weight of fluid discharged through any orifice, such as a space between a valve and its seat, is proportional to the velocity of flow and to the density or weight of 1 cubic foot of the fluid. Multiplying, therefore, the velocities by the weights of 1 cubic foot of the three fluids we find the leakage proportional to the products—viz.:—

With dry saturated steam,
proportional to 2008 × ·2628 = 525.
With steam containing, 5 per cent of water,
proportional to 1952 × ·278 = 543.
With superheated steam at 538°,
proportional to 2244 × ·21 = 471.

The wet steam increasing the leakage by

$$\frac{543 - 525}{325} \times 100 = 3{\cdot}4 \text{ per cent.,}$$

and the superheated steam reducing it by

$$\frac{525 - 471}{525} \times 100 = 10{\cdot}3 \text{ per cent.,}$$

as compared with the leakage of dry saturated steam.

In practice the difference between saturated and superheated steam will be much greater, because with the former no small proportion of the leakage will consist of

* 0·95 lb. of saturated steam at 115 lb. absolute pressure occupies ... ... 3·58 cub. ft.
0·05 lb. of water occupies ... ... 0·009 "
1 lb. of mixture occupies... ... ... 3·589 "
∴ 1 cubic foot weighs 1 ÷ 3·589 lb. = 0·278 lb.

† 1 lb. of saturated steam at 338° occupies 3·8 cubic feet, and when superheated to 538° fills $3{\cdot}8 \times \frac{461 + 538}{461 + 338}$ ... = 4·75 cub. ft.
∴ 1 cubic foot weighs 1 ÷ 475 ... = 0·21 lb.

FIG. 6.

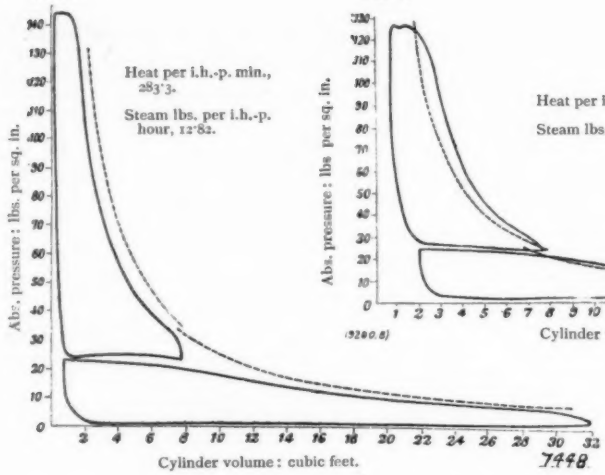
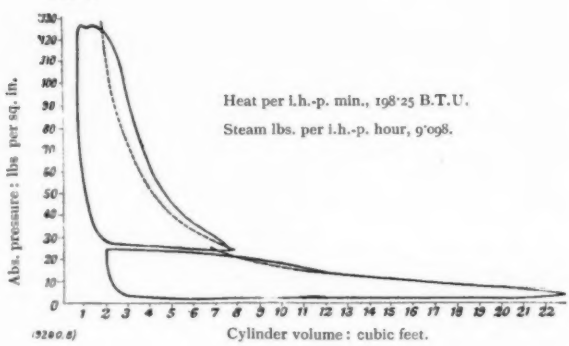


FIG. 7.



water deposited on the valves, valve-seats, and cylinder-walls by condensation of the steam; and as the weight of a cubic foot of water at 100 lb. pressure is 56 lb., the leakage at the lowest of the three velocities above-mentioned—viz,, 1952 ft. per second —will be proportional, so far as the water is concerned, to 1952 × 56 = 10,900, or more than twenty times the largest of the former quantities.

These figures, I think, show that superheating has no inconsiderable effect in reducing valve and piston leakage.

To conclude this portion of the subject, let me refer you to the indicator diagrams, Figs. 6 and 7. They were taken from the two most economical compound engines I have myself tested. Fig. 6 is taken from a pair of side-by-side beam engines with Corliss valves, working with saturated steam. The cylinders are 17 in. and 34 in. in diameter by 5 ft. stroke; speed, 34 revolutions per minute. Both cylinders are completely steam-jacketed, and there is a steam-jacketed reheater between them. They discharge into a surface condenser with 1457 square feet of surface placed practically at the sea-level, and receive an ample supply of cold water.

Fig. 7 is from an inverted vertical engine of the marine type, with piston drop-valves, working with superheated steam. The diameters of the cylinders are 21 in. and 36 in., and the stroke of the piston 3 ft.; speed, 100 revolutions per minute. The main steam-pipe from the superheater bifurcates after passing the engine stop-valve, one branch leading direct, the other through the tubes of an intermediate reheater, to the high-pressure cylinder. The exhaust from the high-pressure cylinder is superheated by passing between these tubes on its way to the low-pressure cylinder. The engine usually discharges into a jet condenser, but to facilitate the measurement of the steam a surface condenser with a surface of about 1200 sq. ft. was used for the trial.

The following are the results of the two trials:—

	Saturated Steam.	Superheated Steam.
Indicated horse-power	221	481
Steam pressure by gauge in engine-house	133	118
Temperature of steam on boiler side of engine stop-valve ..	358° Fahr.	349° Fahr.
Superheat on boiler side of engine stop-valve	..	395 ,,
Superheat at entrance to high-pressure cylinder	..	253 ,,
Superheat at entrance to low-pressure cylinder	..	153 ,,
Temperature of water leaving hot well	74° Fahr.	102 ,,
Steam per indicated horse-power hour	12·82 lb.	9·1 lb.
Equivalent consumption of saturated steam reckoned from hot-well temperature to superheat at boiler side of engine stop-valve	12·82 ,,	10·63 ,,
Saving in steam by superheating	..	17 per cent
Heat consumption reckoned from hot-well temperature per i.h.-p. per minute ..	238 B.T.U.	198 B.T.U.
Saving in heat by superheating per i.h.-p. per minute ..	..	16·8 per cent.

(To be continued.)

The Design of Engineering Workshops—III.

By H. MUNCASTER.

Concrete.—Concrete work for foundations of walls and columns is so generally employed that it will be unnecessary to deal with its application here.

Brickwork.—In designing brickwork it is essential to arrange the dimensions to suit the sizes of the bricks that may be available, and all walls, piers, and offsets must be set out in figures that are multiples of the width of a brick. The recognised size of a brick in England is 9 in. in length by $4\frac{1}{8}$ in. in width. The width is rather less than half the length, as it is important that exactly twice the number of bricks are laid along the face of a wall when the end is towards the face, the difference being due to the extra joints, for which an allowance of (about) $\frac{1}{4}$ in. is required for mortar.

Where two quantities of brick are to be used, as where the wall is faced with a superior quality of pressed brick, and the interior building of a common "stock" brick, care should be taken to ensure the dimensions being practically the same in each case.

It is very desirable that openings in walls where there is much traffic the corners should be rounded off, "bull-nose" bricks being used, which are much less likely to get chipped than square cornered bricks.

To relieve the monotonous appearance of an unbroken wall where no windows are to be fitted, it is desirable to build it in panels—that is, rectangular portions of the works are set back an amount equal to the width of a brick. Sometimes these panels are also separated by a pier, as in Fig. 7, which show in isometrical projection the details of the dwarf wall enclosing a foundry. The wall is of a total height of 13 ft. 6 in. above the foundation, or 12 ft. above ground level to the top of the coping. A wall built thus is more economical for the same amount of brickwork than one with a plain face. The size of the panels will be arranged to suit the spacing of columns. To protect the top of the wall a coping about 10 in. by 12 in. wide is laid on the brickwork. Fig. 8 shows how this coping is arranged to throw off the water running down from the sheeting in wet weather. The coping is moulded of concrete (cement and sand), and laid in lengths of about three to four feet.

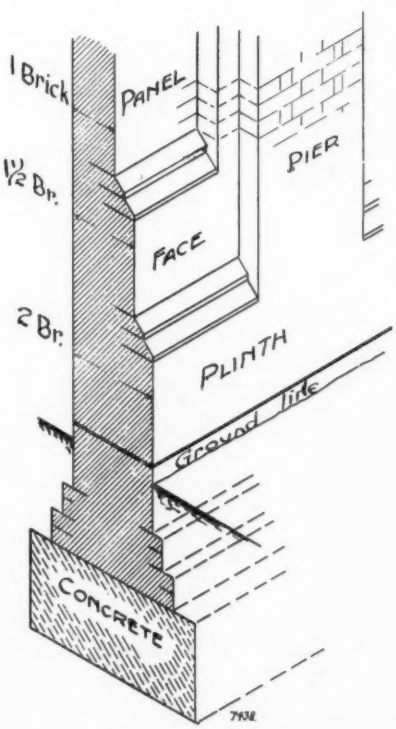


FIG. 7.

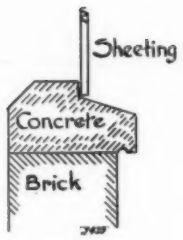
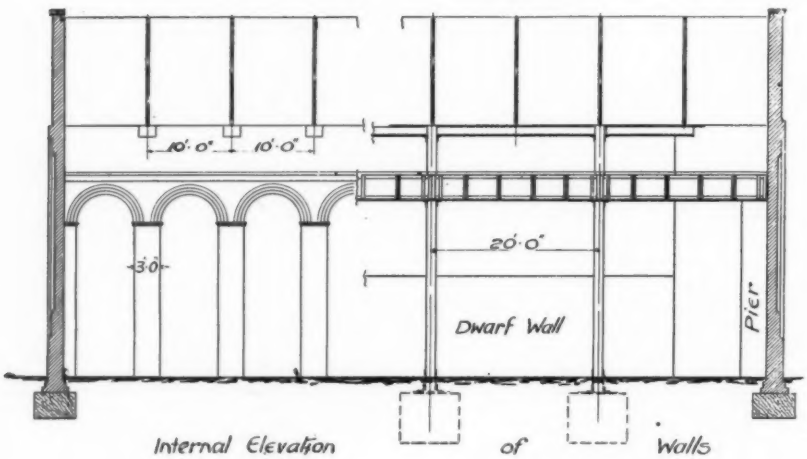
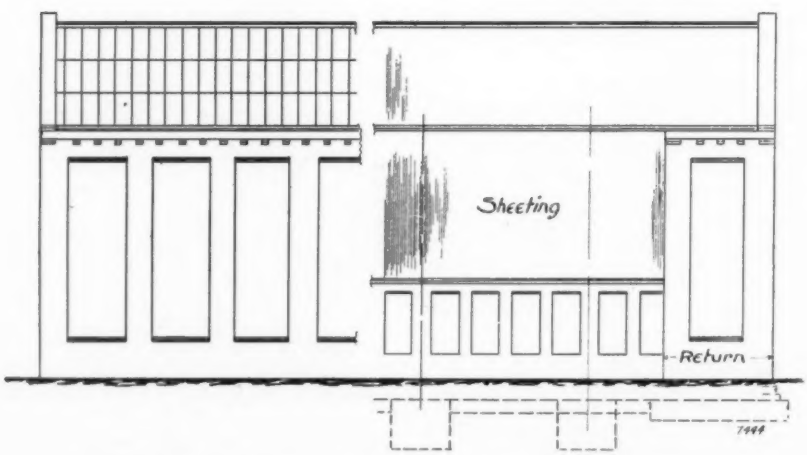


FIG. 8.

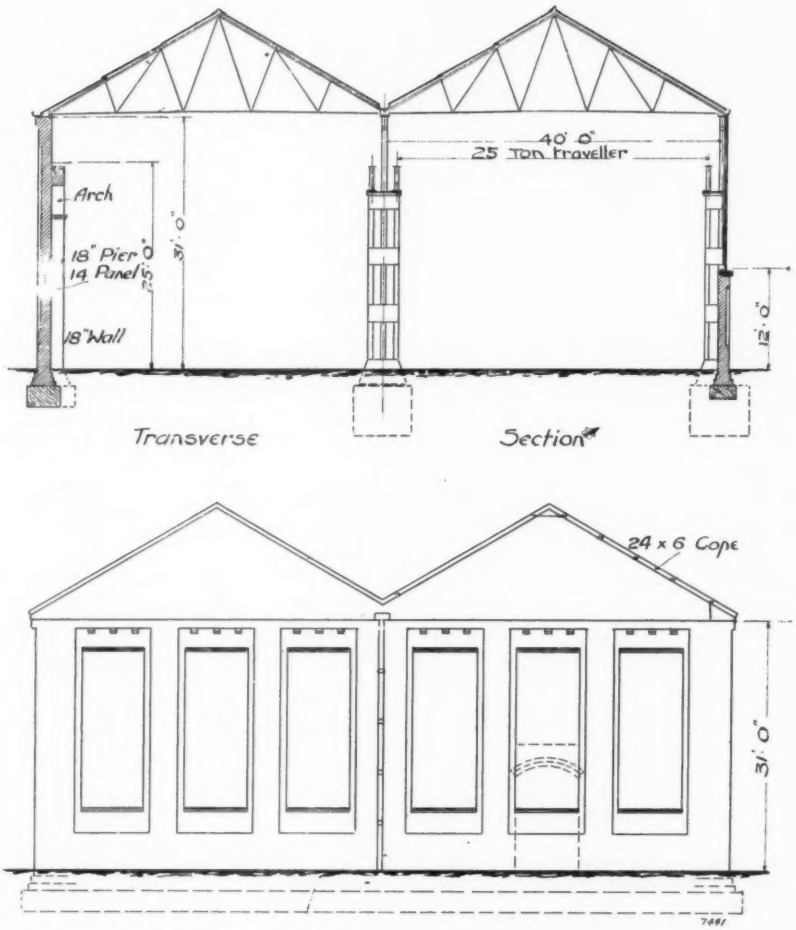
In buildings of considerable length where no transverse walls occur, it is necessary to build piers to support the wall. These piers are useful to carry a gantry girder, or, as shown in Figs. 9 and 11, may have an arch thrown over the space between with an oversailing stone sill, on which the gantry rail rests. This makes a very substantial job, and looks extremely well if nicely built. The piers should be built with round



Internal Elevation of Walls



Elevation to Street. FIGS. 9 AND 10. Elevation to Yard.



FIGS. 11 AND 12.

corners. The external view of the same wall is shown in Fig. 10. It will be noticed that the wall is panelled, and that at the top of the wall an oversailing course of brickwork, on which the gutter rests, is carried on corbels. The object is principally to relieve the plainness of the wall.

The gable walls, as shown in Fig. 12, have a pilaster between the panels. A pier will be required between each gable to act as a buttress and afford sufficient support for the walls.

These views are given as an example of a wall suited for a shop of unlimited length; the walls to the streets to be permanent. At the opposite side of the shop the walls are a compromise, and are so arranged that if the shop be extended in that direction at any time, they can be taken away without leaving any incumbrance. It will be noticed

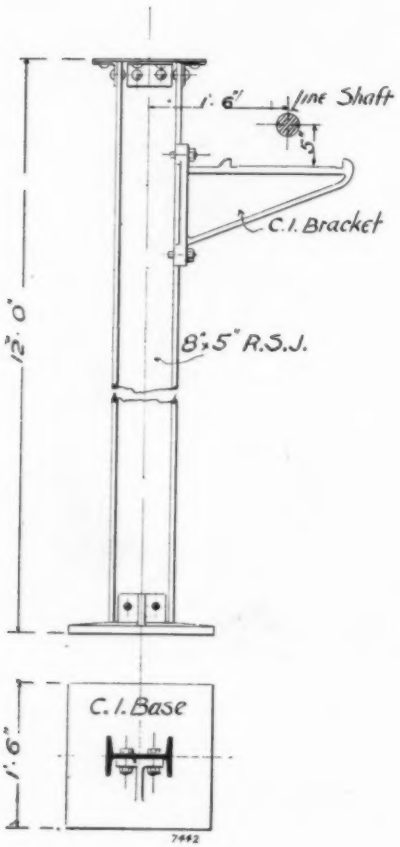


FIG. 13.

that the gable walling is returned on the sheeted side of the shop, the return being necessary for the stability of the gable.

Stonework.—Stonework is not generally so capable of expeditious handling as brickwork, and requires a little more bulk for the same strength on account of the inferior "bond" of the work, due to the irregular shape and unequal size of the various parts. There are cases where, however, it may be used to advantage, especially for the outer walls of buildings of large dimensions.

It must be borne in mind that rubble stonework is quite dependent on the quality of the mortar used, and is generally so built that if the mortar were washed out the whole would collapse. The mortar should therefore, whether of lime or cement, be of very good quality.

Columns. — The employment of a column as a simple strut is of rare occurrence in workshops, as some other duty is generally demanded, such as the carrying of a shafting bracket, derrick, crane gantry, &c. Where it is used to support a wall over a bressemer or carry a gallery, and the load is one of compression in the direction of its length only, a cylindrical cast iron column is most satisfactory, especially if it be desirable to give it some ornamentation. Occasionally a cast column or stanchion of H section is used; but in view of the readiness a column can be built up of rolled steel bars, it is not generally advisable to employ cast iron for such columns.

Of late years a great variety of rolled steel bars, especially of the H sections, have been put on the market, and are obtainable up to nearly 30 in. in depth by 12 in. in the width of flanges.

These bars are very suitable for the making of stanchions or columns, and when properly selected and used under suitable conditions, have many advantages over cast iron columns.

As the material is more reliable, a lighter section in rolled steel can be safely used than would be allowed in cast iron, so that in columns made out of rolled bars the cost is less, and as the flat surfaces offer a convenient means of attaching shafting brackets, gantries, derricks, joists for flooring, &c., the H section rolled joist has found favour with the structural engineer. Where shafting has to be carried, or where gantries have to be supported on brackets attached to the sides of the columns, the stresses are such that a much higher moment of inertia is required in one direction than in any other direction.

The cylindrical column is not in this respect so satisfactory as the H section, which offers the advantage, when

properly placed, of an increased moment of inertia in the desired direction. Fig. 13 shows a column of such a nature. Besides acting as a support for the roof, it has to carry a heavy line of shafting at some distance from the face of the column, resting on a cast iron bracket, fixed to the flange of the column by means of hook bolts. The flange offers a very handy means for such an attachment, and the section shown gives the high moment of inertia necessary to meet the stress due to the weight and vibration of the shafting, and to the pull of the belting driving the machinery. The sketch shows how the roof principal is fixed to the top of the column; angles are riveted to the flanges and to the web and rather flush of the end, so as to allow a plate rest entirely on the angles to which it is riveted by countersunk rivets.

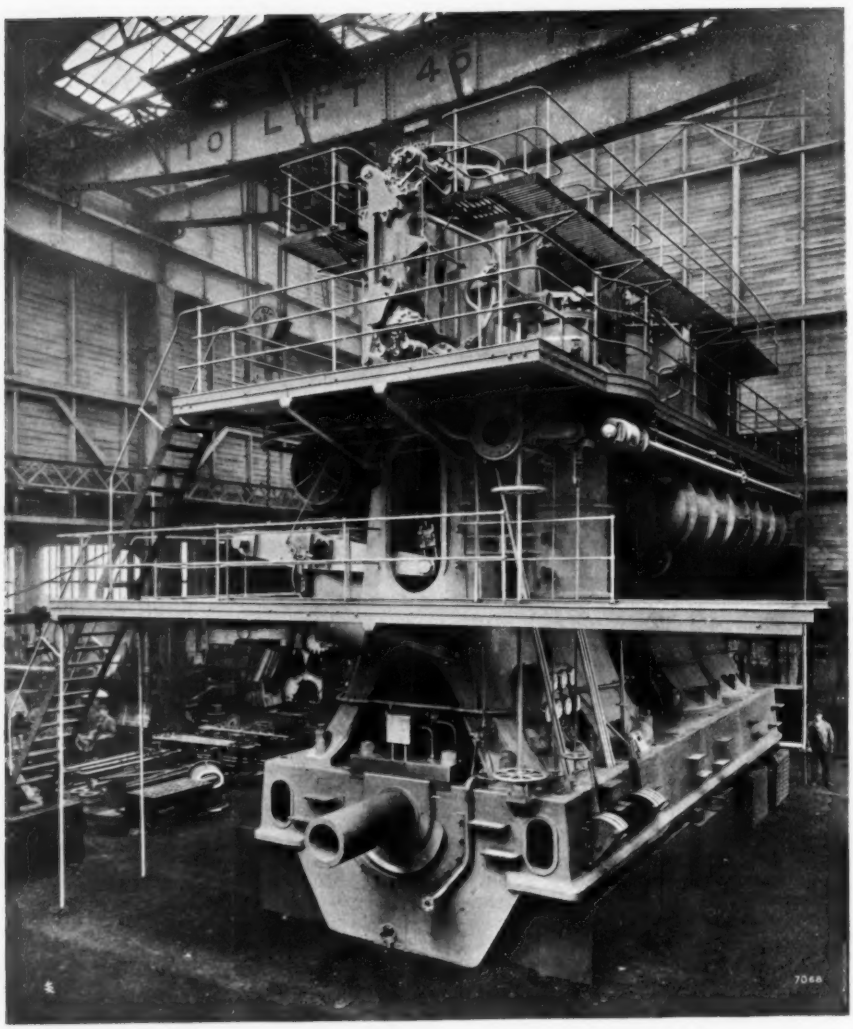
(To be continued.)

The 6,000 I.H.-P. Manchester Corporation Engines.

AMONGST the largest slow-speed vertical engines now running are those installed some months back at the Stuart Street power station of the Manchester Corporation. They consist of two sets, each of the four-cylinder triple expansion type, designed to work either condensing or non-condensing without alteration to the setting of the valves. At full-load condensing each engine will indicate 6,000 h.-p., and is capable of developing 6,500 h.-p. for a period of two hours; non-condensing, 5,000 h.-p. is developed. The normal running speed is 75 revolutions per minute, and the working pressure is 190 lb. at the stop-valve, superheating being carried up to 500° Fahr. The cylinders are all fitted with separate liners, the space formed between them and the cylinder castings being used for steam jacketing purposes. The ends are also steam jacketed, and the whole cylinder is covered with asbestos lagging. The following are the cylinder dimensions:—high pressure, 37 in. diameter; intermediate, 59 in.; and low pressure, 72 in.; all with a stroke of 5 ft. "Corliss" valves worked by "Dobson-Corliss" trip-gear are fitted throughout. The main governor is of the "Whitehead" type and an "Aspinall" emergency governor is also provided, which comes into action and shuts the engine down when the speed increases by more than 6 per cent. Between the high pressure and intermediate cylinders, and also between the latter and the low-pressure cylinders, receivers are fitted. Those between the intermediate and low pressure cylinders are arranged for reheating the intermediate exhaust by means of live steam. The weights of the main parts are of interest. The fly-wheel, which forms the revolving field of the alternater, weighs 75½ tons, or 112 tons when the magnets are included; the crank-shaft, which is in two lengths, coupled together, weighs 62 tons, and the bed-plates, which also act as oil tanks, 85 tons each.

The specification required an efficiency of 91 per cent. and a steam consumption of not exceeding 11 lb. per i-h.-p. hour, with a 27 in. vacuum, and superheated steam at a temperature of 500° Fahr. When running non-condensing the steam consumption was limited by the specification to 18 lb. per i-h.-p.

We are indebted for the foregoing particulars and photograph to the builders, the Wallsend Slipway and Engineering Co., Ltd., of Newcastle-on-Tyne.



6,000 I.H.-P. ENGINES AT THE STUART STREET POWER STATION, MANCHESTER CORPORATION

Locomotives and Railways.

By CHAS. S. LAKE.

Compound Locomotives : Great Central Railway. — Drawings have already appeared, and reference has been made, in these notes to the 3-cylinder compound locomotives of the 4-4-2 type for working express passenger traffic on the Great Central Railway. Two engines of this description are now in service, having been constructed at the company's works, Gorton, to the designs of Mr. J. G. Robinson, M.Inst. C.E., chief mechanical engineer.

The system of compounding employed is that devised by Mr. W. M. Smith, upon which locomotives have been built for the North Eastern* and Midland Railways. The engines may be worked either as semi-compounds or compound at the will of the driver, who is provided with mechanism for adapting the style of working to meet the varying conditions met with in the course of a run.

When the regulator is opened for compound working, steam is admitted to both the high and low pressure cylinders; to the latter at a reduced pressure through a valve, and direct from the boiler to the high pressure cylinder. The spring of the reducing valve is set to pass steam at 50 lbs. pressure to the low pressure steam chest.

On the first exhaust from the high pressure cylinder, steam from the boiler is cut off and the valve closes, the pressure gauge in the cab indicating the pressure in the low pressure steam chest; the engine then continuing to work compound. For semi-compound working, the driver is provided with a hand-wheel in the cab marked "steam to low pressure cylinders," and by turning this, the spring in the controlling valve is compressed (a rod passing through the hand-rail forms a connection between the wheel and the valve); the pressure in the low pressure steam chest is increased and may be fixed at any pressure between 50 lbs. and 150 lbs. per sq. in. by locking the hand-wheel mentioned above.

The back pressure on the high pressure piston is increased, and the forward pressure reduced by the amount the forward pressure in the two low pressure cylinders is increased; or, in other words, the power in one cylinder is reduced whilst being augmented in the other two. If the initial pressure were 100 lbs. in the high pressure it would be the same in the low pressure; if 150 lbs. in the low pressure it would be 50 lbs. in the high pressure.

The combined effective initial pressure in the cylinders being say 200 lbs. per sq. in., this pressure can be divided in any proportion between the high and low pressure cylinders, but in no case should the cut-off in the low pressure cylinders be less than 40 per cent. To get well away with a heavy train it may be necessary to have the pressure gauge in the cab, indicating the pressure in the low pressure steam chest, at anything between 100 and 140 lbs. pressure.

The non-return valves which connect the ends of the high pressure cylinder to the receiver are automatic, and only act when the engine starts, when steam from the receiver gets through the exhaust side of the valve and acts on the piston in the opposite direction, and the valve covers the steam port; then the steam in the receiver acts and opens the valve, thus admitting steam to the other side of the piston, and putting it in equilibrium when the steam is admitted from the high pressure steam chest to the cylinder. The end of the cylinder is in connection with the top of the non-return valve, and the pressure in the high pressure cylinder being always greater than the pressure in the receiver the valve remains shut; it is only at starting, and occasionally these valves come into action. They do not in any way affect the driver.

* In the case of the North-Eastern only one engine of this type is in use at present, and this was converted from a 2-cylinder Worsdell compound to a 3-cylinder engine on Smith's system.

The high pressure valve is Smith's patent segmental piston valve (10 in. diameter) with cast iron rings, working in cast iron bushes, having the steam ports (not shown on drawing) divided by diagonal bars. The low pressure valves are ordinary D valves of bronze. The three valves are each worked by separate link motions. The low pressure eccentric rods being set to clear the crank axle. It will also be noticed that the high pressure pistons do not fit the covers, as it is necessary with compound locomotives to allow plenty of clearance.

The principal dimensions are as follows:

Cylinders, high pressure (1) (inside) ...	19 in. by 26 in.
Cylinders, low pressure (2) (outside) ...	21 in. by 26 in.
Coupled wheels	6 ft. 9 in. dia.
„ wheelbase	7 ft. 3 in.
Total „	27 ft. 9½ in.
Boiler length	15 ft.
„ diameter (outside at front end)	4 ft. 9½ in. dia.
„ centre line above rails ...	8 ft. 6 in.
Heating surface:—tubes (No. 221, dia 2 in. outs.)	1,778 sq. ft.
„ „ fire-box ("Belpaire" type)...	153 sq. ft.
„ „ total	1,931 sq. ft.
Grate area	26 sq. ft.
Working pressure	200 lbs. per. sq. in.
Weight in working order	71 tons
Adhesion weight	37 tons

The tender runs upon six 4 ft. 3 in. diameter wheels arranged on a base of 13 ft., and carries 4,000 gallons of water and five tons of coal. It is fitted with water pick-up apparatus, operated by Mr. Robinson's patented screw and steam cylinder arrangement, which the writer has frequently tested under running conditions, and found to admirably answer its purpose. The scoop is provided with a hood for preventing waste of water, that being one of the chief objections to the use of pick-up apparatus.

The engines will work in competition with others of the same general type, but having two simple cylinders only as illustrated and described in last month's notes. These new compounds have been so designed that, in the event of their not proving superior to their non-compound contemporaries, the inside cylinder and motion may be easily removed, and the engines run as 2-cylinder simple locomotives. Presumably the cylinders would in that event be bushed so as to reduce their diameter, as neither the heating surface of 1,931 sq. ft., nor the existing adhesion weight of 37 tons, can be considered as strictly in proportion with two 21 in. by 26 in. cylinders taking steam direct from the boiler. Steam is distributed to the high pressure cylinder by a piston valve (Smith's segmental type) working underneath, and actuated by link motion driven off the high pressure driving axle. The low pressure cylinders have D-shaped slide valves at the sides inside the framing, with similar gearing driven off the low pressure driving axle.

The Cost of Locomotive Operation.—In the course of an interesting article contributed to the *Engineer* by Mr. W. Pollard Digby, a detailed comparison of the cost of operating locomotives on the Great Central, Great Western, and London and South Western Railways was set forth in the form of tables. These were arranged to show the total wages cost of working locomotives, the total cost of coal and coke used in firing them, wages cost per locomotive, and fuel cost per locomotive, over a period of seven years, 1898 to 1904 inclusive. The tables are reproduced herewith and are as follows:

TABLE I.—WAGES AND FUEL COSTS FOR GREAT CENTRAL LOCOMOTIVES.

Year.	1898.	1899.	1900.	1901.	1902.	1903.	1904.
	£	£	£	£	£	£	£
Total wages cost of working locomotives	210,844	251,675	259,494	251,563	263,613	276,751	287,104
Total cost of coal and coke for locomotives	162,320	241,646	350,436	317,030	260,836	259,094	255,639
Wages cost per locomotive...	244	280	271	254	252	260	270
Fuel cost per locomotive	188	268	363	320	249	244	240

TABLE II.—WAGES AND FUEL COSTS FOR GREAT WESTERN LOCOMOTIVES.

Year.	1898.	1899.	1900.	1901.	1902.	1903.	1904.
	£	£	£	£	£	£	£
Total wages cost of working locomotives	591,790	649,719	667,373	666,878	667,522	688,059	700,763
Total cost of coal and coke for locomotives	451,901	538,285	731,272	831,571	683,817	615,896	601,553
Wages cost per locomotive	314	336	336	324	317	313	308
Fuel cost per locomotive	240	222	367	403	325	280	264

TABLE III.—WAGES AND FUEL COSTS FOR LONDON AND SOUTH WESTERN LOCOMOTIVES.

Year.	1898.	1899.	1900.	1901.	1902.	1903.	1904.
	£	£	£	£	£	£	£
Total wages cost of working locomotives	234,633	231,040	241,972	247,951	256,030	258,692	263,931
Total cost of coal and coke for locomotives	264,487	272,427	339,326	382,908	327,396	311,869	317,382
Wages cost per locomotive...	334	331	330	338	349	351	359
Fuel cost per locomotive	377	374	403	522	446	424	431

It is difficult to arrive at the true reason for the excess of wages and fuel costs per locomotive on the London and South Western Railway as compared with the other two railways quoted, but it is doubtless attributable, in a large measure, to the fact that the first named line is much less favourably placed as regards accessibility to the source of its coal supply than are the Great Central and Great Western Railways.

A Well-Designed High-Speed Lathe.—The writer has received from Messrs. Dean, Smith and Grace, Ltd., of Keighley, Yorks, a photograph reproduced herewith, and particulars of their standard 12 in. high-speed lathe, large numbers of which have been supplied to various locomotive shops throughout the world.

In this lathe the bed is of strong section and is rigid under the heaviest cutting. The sliding and wearing surfaces are large, and the standards of the bed are arranged to form covenient tool cupboards.

The headstock is exceptionally powerful, and the steel spindle, which is accurately ground, runs in ample parallel bearings of phosphor bronze. The large diameter of the cone and the width of belt enable the requisite power and speeds to be obtained with ease. The cone and gearing are correctly graded, and a range of speeds suitable for all classes of work are obtained, these speeds being:

Single gear: 560, 430·6, 332, 255·4, 203·4, 156·4, 120·7, and 92·8.

Double gear: 70, 53·6, 41·5, 31·8, 25·8, 19·4, 15 and 11·4.

A reversing motion is placed on head stock, and also the makers' patent lubricating device, which assures a plentiful supply of oil to the cone bearings when on the highest speeds.

The loose headstock is proportionately massive, being held down by four bolts. It is divided for taper turning, and the spindle is truly ground. The centre is fitted with a patent lubricating device for lubricating it for high-speed work.

The saddle has large bearing surfaces, and has powerful apron friction. The feeds are easily worked, and the compound rest has graduated swivel arrangement for taper turning. The gearing in the apron is supported on two bearings instead of one, as is general. The rack pinion is cut from the solid, and is supported underneath the

12-IN. CENTRE HIGH-SPEED LATHE AT WORK ON STEEL FORGINGS.

rack. The rack and pinion are supported against side pressure when under heavy cuts, and the whole of the gearing, with the exception of the worm, is made from steel stampings.

The self-acting feeds in the gear box are positive, and are contained in the box on the front of the bed, being easily altered. The gearing is practically indestructible as the whole of the clutch mechanism is made from steel stampings, case-hardened.

The leading screw is $\frac{1}{2}$ in. pitch, and its accuracy in the aggregate is guaranteed to be within one-hundredth of an inch in a length of six feet.

The illustration shows the lathe at work on forgings at 80 ft. per minute. Messrs. Dean, Smith and Grace, Ltd., state that they have recently completed an order for fifty-five of these tools for one firm alone.

Replies to Correspondents. — Referring to the subject of the new Great Central route to London, mentioned in the January notes, a correspondent writes :—

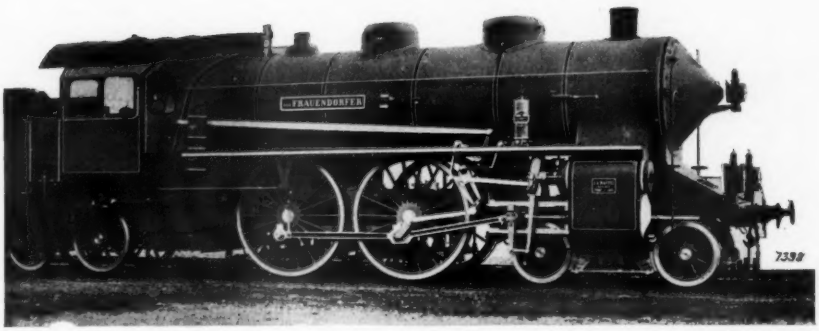
"In the concluding note for January, it is stated that at the present time the Great Central Railway have at disposal as fine a stud of locomotives as could be wished for, which is more than could be said at the time of the opening of the original London extension. This seems to me a little unfair, as it is indisputably the fact that Mr. Pollitt's engines left nothing to be desired in point of design and construction."

In making the remark quoted above, the writer was referring more specifically to the numerical shortcomings of the Great Central Railway locomotive stock at that time, in view of the added requirements brought into existence by the opening of the new line. Apart from that, however, no one will deny that, from the point of view of all round efficiency, the locomotives designed by the present chief mechanical engineer are superior to those of his predecessor, Mr. Pollitt. Their power capacity is greater by far, and the number has been increased out of all proportion to what it was when traffic over the original extension line commenced. Those who were then in a position to judge agreed that the want of success met with at first with the new undertaking was largely attributable to the unfortunate shortness of locomotive power which existed.

Another correspondent writes :—

"Having been absent from England for a number of years, and not being able for various reasons to give much attention to the progress made in this country in connection with locomotive engineering, I am surprised to find on my return what little headway has been made with locomotive compounding here. About the time that I left home to take up a position on the Continent, Mr. Webb, of the London and North Western Railway, was becoming prominently associated, in the minds of those who follow these matters, with the introduction of compound locomotives, and I remember being much impressed with the individuality he displayed in seriously taking up a problem which other engineers holding similar positions on home railways appeared to be either unwilling or afraid to deal with. . . . My sojourn abroad has given me an opportunity of watching the triumphant and uninterrupted development in the use of the compound principle as applied to locomotives in all parts of the Continent, so much so, that it is a rare thing nowadays to find simple engines working any class of railway traffic there. I was much interested in reading in THE ENGINEERING REVIEW for January, the spirited advocacy of the compound locomotive which appeared on page 48, but I have been as much surprised to read in another journal a smart denunciation of the same kind of engine, accompanied by a statement to the effect that Mr. Webb's compounds on the London and North Western Railway are being sent to the scrap heap as fast as possible, a process which appeared to give the writer unbounded satisfaction."

The best reply to this correspondent is perhaps to advise him, now he is back in this country, to closely watch the trend of events in connection with the subject he writes upon. It will be surprising if he does not see a development of the movement in favour of compound principle on British railways, now that it is at last being subjected to more exhaustive trial. As regards the criticism of Mr. Webb and his engines the correspondent, had he been here to observe it, would know that, during the last few years, a school of irresponsible critics has arisen, the members of which have always made a strong point of denouncing the methods employed by that distinguished locomotive engineer. Even now, some years after Mr. Webb's retirement from the post which he filled for thirty years or more with such conspicuous ability, some of these critics, who include among their number an auctioneer, a clergyman, a barrister (briefless, more or less), and other gentlemen equally well qualified to speak upon the subject of engineering (locomotive or otherwise), seem to be unable to write upon the subject of London and North Western locomotive practice without introducing, in some shape or form, unfavourable references to the policy adopted by Mr. Webb. The



4-4-2 TYPE EXPRESS LOCOMOTIVE FOR THE PFALZ RAILWAYS.

latter will, however, always be remembered as the pioneer of British locomotive compounding, and whatever ultimate success may be accomplished on our railways in this connection, his name will be indelibly associated with the history of progress, despite the number and vehemence of his non-professional critics.

A Remarkable German Locomotive.—In the accompanying illustration is shown one of the latest and largest examples of German locomotive design and construction. The engine, which is a 4-cylinder compound with the "Atlantic" (4-4-2) wheel arrangement, has been built by the firm of J. A. Maffei, of Munich, for working fast and heavy passenger traffic on the Pfalz system of railways. The four cylinders are arranged in line below the smoke-box on the same transverse plane; two, the high pressure, being inside the frames, whilst the other two (low pressure) cylinders are outside, all driving the same axle, viz., that of the leading pair of coupled wheels. The steam chests are placed above the cylinders, and steam is distributed to the latter by piston valves through the medium of Walschaert's valve gear. The boiler is of large proportions with a conical front end and the wide type of fire-box. The barrel contains a "Pielock" superheater, for which appliance it is claimed that the results show greater economy than those obtained with smoke-box superheater, because of its being placed where the gases are at the highest temperature, so that the heating power not used for superheating is employed for further heating the water surrounding the tubes. It is further claimed for this type of superheater that there are no parts under pressure and no wearing surfaces.

The cab is of very commodious design, with pointed front to lessen the effect of wind resistance. An eight-wheeled (double bogie) tender accompanies the engine, which has the following dimensions:—

Cylinder high-pressure (2)	14⅜ in. dia.
,, low-pressure (2)	23⅝ in. dia.
Piston stroke ... ... ,, ...	25⅝ in.
Coupled wheels dia.	6 ft. 7 in.
Wheelbase engine	32 ft. 10 in.
Boiler, number of tubes	285
Heating surface tubes	2,248·8 sq. ft.
,, ,, fire-box	148·4 sq. ft.
,, ,, total	2,396·12 sq. ft.
Grate area	40·8 sq. ft.
Heating surface in superheater	448·6 sq. ft.
Weight of engine in working order ...	74·27 tons.

The tender weighs 21·3 tons empty and 47·3 tons loaded. It has capacities for six tons of coal and 4,000 gallons of water.

The coupled wheels are unprovided with splashers, the running board being raised to clear them. Bar-framing is used, the driving-wheel springs are "equalised," and brake blocks are fitted to the bogie wheels as well as the others. Westinghouse apparatus is employed for applying the brakes.

English *versus* American Railway Wagons.—Another instance, demonstrating the superiority of English over American methods in connection with the design and construction of railway rolling stock, has recently come to hand. Mr. Hatah, the chief locomotive superintendent of the Japanese Imperial Government Railways, after inspecting some mineral wagons supplied by a well-known English firm, and also a number sent out by an equally prominent firm in the United States, expressed his deep satisfaction with the equipment and finish of the British wagons, bestowing unequivocal praise both upon the material

used and the quality of the workmanship, which he described as being of the highest and most conscientious description.

Mr. Hatah gave further expression to his gratification in which the order had been carried out.

The American made wagons, on the other hand, are described as "the shoddiest-looking vehicles I have ever seen; a disgrace to the works from which they had been turned out, and to the nation which had allowed such rubbish to leave the country." In looking at the finish of the British work as compared with that of American there could be no comparison; the former showed well-finished and faithfully executed work; the latter a disgracefully shoddy job with bad material into the bargain. Moreover, the American wagons were found to be neither of uniform size or carrying capacity. Mr. Hatah had no hesitation in expressing his disgust with the character of the American products.

The cars now being imported for London traffic on the Underground Electric Railways Co., Ltd., from the United States are samples of American workmanship, and readers will shortly have an opportunity of judging for themselves.

Sterilising Railway Cars. — Under the State laws of Texas and Kentucky, the sterilisation of railway cars is compulsory at periods of from three to fifteen days, and an agitation is in progress, says the *Railway Age* of Chicago, for the enforcement of similar laws in Ohio. The management of the Erie Railroad, believing that such laws will become general, has taken the anticipatory step of thoroughly sterilising trains at Jersey City after each round trip between Jersey City and Chicago, a run of about two thousand miles, and, as soon as arrangements can be completed, the process will be extended to other trains on the line. A device has been perfected by the principal chemist of the Erie Railroad's mechanical department by means of which cars are freed from all disease germs and noxious odours, and the Pullman Company, after investigating the method, has consented to all bedding, clothing, and hangings in their cars used on the trains being submitted to the sterilising process. This consists of mixing two chemicals so that a formaldehyde gas bath is given to each car, which is tightly closed for the purpose at the end of each round trip.

A deodorising apparatus has also been devised and installed on fifteen Erie club, parlour and commuter cars. The apparatus is placed under the seats out of sight of the passengers, and gives off an odourless gas which combines with the stale tobacco smoke or other offensive odours which may accumulate in the cars, and serves to completely nullify them. The process is an entirely new one, and it is claimed for it that after a night's treatment the air in the car is as fresh and pure as that out of doors, a fact which has been noted and commented upon by passengers.

Provided this deodorising process can be carried on without causing any injury or inconvenience to passengers, there appears to be a future for it. How welcome some such device would be in certain stuffy compartment carriages in this country those who use them will agree, and especially would this have been the case in the pre-electric days of the underground lines, when the most elementary rules of hygiene were, as a rule, impossible of observation.

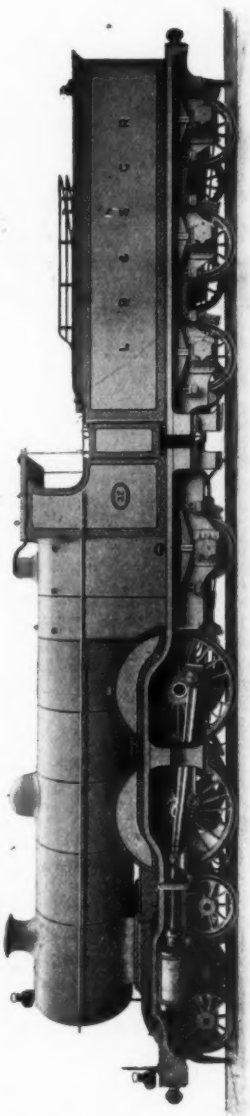
Atlantic-type Locomotives for the London, Brighton and South Coast Railway.—Mr. D. Earle Marsh, the new locomotive superintendent of the London, Brighton and South Coast Railway, has opened his account in designing locomotives for that line by placing five "Atlantic" (4-4-2) type engines in service for working the heaviest passenger traffic. As was to be expected, the new engines follow very closely upon the lines of those built at Doncaster* for the Great Northern Railway, many of which were put to work during the year or so prior to Mr. Marsh's relinquishment of the position of assistant locomotive engineer and works manager there to become chief at Brighton. Those who properly understand the conditions of traffic on the London, Brighton and South Coast Railway will appreciate the necessity which exists thereon for the employment of powerful locomotives. Like the Lancashire and Yorkshire, it is a small railway which requires large engines, and the late Mr. Stroudley showed that he recognised this to be the case by introducing powerful four wheels coupled locomotives having 18½ by 26 in. cylinders, 175 lbs. steam pressure, and 1,485 sq. ft. of heating surface. This was in 1882, and the figures—especially those relating to the boiler—were then considered remarkable. His successor, the late Mr. R. J. Billinton, who of course had to provide against still more arduous conditions of service, built several 4-4-0 type locomotives having cylinders 19 by 26 in. and coupled wheels 6 ft. 9 in.; the boilers carrying a

* The enlarged "Atlantic" type engines of the 251 class on the Great Northern Railway are here meant.

working steam pressure of 180 lbs. per sq. in. and, with the fire-box, containing 1,635 sq. ft. of heating surface, the grate area being 24 sq. ft. In Mr. Marsh's new engines the cylinders are 18½ in. diameter with a piston stroke of 26 in. and other dimensions are as follows:—

Coupled wheels	6 ft. 3 in.
Trailing wheels	3 ft. 6 in.
Centres of bogie wheels...	6 ft. 3 in.
,, ,, to centre of driving wheels	15 ft. 1 in.
,, coupled wheels	6 ft. 10 in.
,, driving and trailing wheels	8 ft.
Wheel-base...	26 ft. 4 in.
External diameter of boiler barrel ...	5 ft. 6 in.
Length of boiler barrel	16 ft. 3⅞ in.
Centre line from rail level	8 ft. 8½ in.
External length of fire-box	5 ft. 11 in.
External width of fire-box	6 ft. 9½ in.
Depth from centre line of boiler (front)	5 ft. 1⅞ in.
,, ,, ,, (back)	4 ft. 7½ in.
No. of tubes	246
Length of tubes	16 ft.
Diameter of tubes outside	2¼ in.
Grate surface	30 ft. 9 in.
Heating surface of fire-box	141 sq. ft.
,, ,, tubes	2,318 sq. ft.
,, ,, total	2,459 sq. ft.
Working pressure of boiler	200 lb. per sq. in.
Capacity of tender tank	3,500 gallons.
Total wheel-base of engine and tender	50 ft. 3 in.
Total length over engine and tender buffers	59 ft. 8 in.

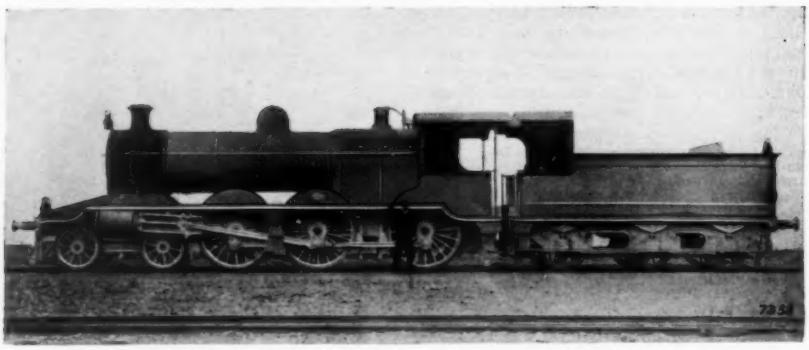
The fire-box is of the short wide type resting on the engine frames. As compared with the Great Northern (251 class) locomotives it contains less heating surface, and the total of 2,473·5 sq. ft. is short by 76·5 sq. ft. of that of the other engines referred to. On the other hand, the cylinders are slightly smaller and the working pressure considerably higher, so that the two designs are virtually equal, all things considered. The margin of power is on the side of the Great Northern locomotives, which have, of course, to deal with heavier all round loads than those on the London, Brighton and South Coast Railway. The engine illustrated is reversed by hand screw and air pressure. Davies and Metcalfe's exhaust steam injectors are used for feeding the boiler.



"ATLANTIC" TYPE EXPRESS LOCOMOTIVE, LONDON, BRIGHTON AND SOUTH COAST RAILWAY.

Recent British Locomotives for Abroad.—Just before the close of the past year Messrs. Robert Stephenson & Co., Ltd., completed at their Darlington works some powerful locomotives for service abroad. These comprised five heavy passenger locomotives of the 4-6-0 type for the Oudh and Rohilkund Railway, India, and a "Decapod" type freight engine for the Argentine Great Western Railway.

The Indian locomotives, one of which is shown in Fig. 1, have outside cylinders driving the intermediate pair of coupled



4-6-0 TYPE PASSENGER LOCOMOTIVE FOR THE OUDH AND ROHILKUND RAILWAY.

wheels, the axle of which is located just in front of the firebox. The latter is of the "Belpaire" type, with two "Ramsbottom" safety valves loaded to 180 lbs. per sq. in. mounted upon it, whilst the boiler, which is pitched with its axis 8 ft. 9 ¾ in. above rail level, contains 206 tubes of 2 in. external diameter, providing 1,510 sq. ft. of heating surface, to which is added 142 sq. ft. contributed by the firebox, a total of 1,652 sq. ft.; the grate area is 29·5 sq. ft.

The cylinders have a diameter of 19 in. and a piston stroke of 26 in., and the coupled wheels are 6 ft. 2 in. dia. on tread. The valve gearing, which is inside the frames and driven off the second coupled (or driving) axle is of the ordinary link motion type, actuating balanced slide valves of the "Richardson" type working at the sides of the cylinders.

In working order the engine without tender weighs 61·8 tons, this load being distributed as follows:—On leading bogie, 15·12 tons; on leading coupled wheels, 15·5 tons: on driving coupled wheels, 15·55 tons; on trailing coupled wheels, 15·7 tons; the adhesion weight thus amounts to 46·75 tons.

The total wheelbase of the engine and tender is 51 ft. 4⅜ in., and the total length over buffers 61 ft. 10⅜ in. The tender, running upon six wheels of 3 ft. 7 in. diameter, has a capacity for 3,000 gallons of water, 7½ tons of coal, and 4 tons of wood. The tractive force of the engine calculated at 90 per cent. of the boiler pressure is 20·548 lbs., the ratio of tractive force to adhesion being as 1 to 5·09.

In addition to the five locomotives despatched in November last a similar number, of identical design, have since been completed at the builders' works, and are in course of being shipped to India. These locomotives are among the heaviest in use on Indian railways, and it will be agreed that they are of handsome and striking appearance. They will work the through mail trains between Benares and Saharanpur *via* Lucknow. This line is laid out upon the 5 ft. 6 in. gauge.

Great Central Developments.—We notice that important alterations and acclerations and additions will be made from March 1st in the London Suburban train service serving the Aylesbury and Chesham lines. The Marylebone terminus of the Great Central Railway is the pivot around which the perfected facilities will operate. As is well-known, Pinner, Northwood, Amersham, Chesham, Aylesbury, etc., have for years been popular residential centres, but it must be admitted the train service hitherto provided has been inadequate. The new accelerations and additions of trains is sure to meet with success and develop the districts. From March 1st, Marylebone Station will also be the centre of the inauguration of a new suburban route for the London man. The new line from Neasden to Akeman Street, passing through South Harrow, Beaconsfield, High Wycombe, and Princes Risboro, at present only open for goods traffic, will, on the date mentioned, be opened for passenger traffic as far as South Harrow Station, and on April 2nd, the throughout section of over 40 miles will be served by an excellent service of passenger trains.

Automobile Engineering Notes.

By ROBERT E. PHILLIPS, M.I.Mech.E., A.M.Inst.C.E.

Oppositely Arranged Inclined Cylinders.—The employment of a large number of cylinders has called into practice a design which, although often used in the early days of mechanical traction, has never succeeded in retaining a permanent hold in the field of constructional design. We refer to the oppositely arranged inclined cylinders. It is now fully recognised that an undue length of wheelbase makes a vehicle difficult to handle, more especially in town traffic. The limit of proportion of length of chassis taken up by the motor seems to have been reached with six-cylinder engines, hence we find the cylinders of the eight-cylinder "Rolls-Royce," arranged in pairs inclined to one another.

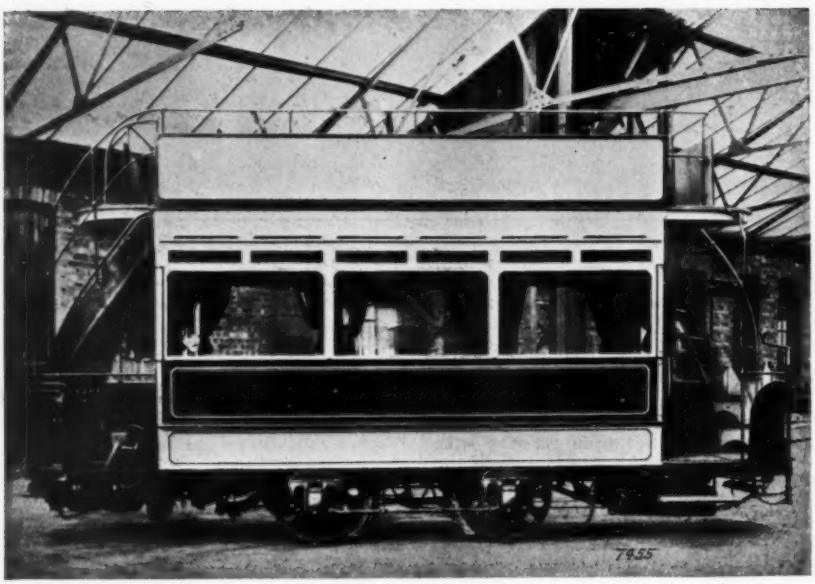
The same arrangement is followed in the 200 h.-p., eight-cylinder racing "Darracq" which has recently accomplished such wonderful times, though the reason for this disposition of the cylinders in this vehicle, was probably a different one, viz., to enable the total weight to be kept within the recognised official limit of 2,000 kilos.

Bouchet, the well-known French constructor, has recently introduced a three-cylinder engine which is a further development of the inclined cylinder design, and may be the forerunner of a type which in the near future may be extensively used where economy in engine space is of importance. In this engine one cylinder is arranged vertically and the other two—one on each side—inclined at an angle of 45 degrees thereto, the three connecting rods working on the same crank. The bore and stroke are both $3\frac{1}{8}$ in., and at a speed of 1,200 revolutions per minute the engine develops 12 h.-p., while the total weight of the engine is but slightly over 50 lbs.

The "F. I. A. T." Commercial Vehicles.—The "F. I. A. T." commercial vehicles, to which we referred in our notice of the Salon de l'Automobile, have now put in an appearance on this side of the Channel, and one of them in the form of an omnibus demonstrated its capabilities by a run from London to Edinburgh, a distance of 400 miles, in 32 hours. These vehicles, which have an established reputation in their own country, by reason of the extensive use to which they are put in the Italian army, are made in two sizes, the one fitted with a 16 h.-p., engine and the other with a 24 h.-p., engine, both chassis having standard pattern engines and gear boxes.

The former is adapted for light and the latter for heavy work. The heavier class, of which the omnibus before referred to is a sample, has a rolled steel frame of ample proportions to carry a full sized double deck omnibus body, but in order to shorten the wheelbase to facilitate manœuvring, the front axle is set back behind the engine while the available area of platform is increased by placing the driver's seat above the engine, so that the floor boards form the top of the bonnet and the dashboard is in a line with the radiator. This in no way interferes with the get-at-ability of the engine, as by removing the floor boards and the side shields, the entire engine is at once exposed. The engine has a bore of approximately 5 ins. and a stroke of slightly less than 6 ins. The valves are placed in opposite sides of the cylinders, the two cam shafts driving the magneto and pump respectively, the latter being placed about midway in the length of the engine, where it is easily reached, and its position enables the pipe running to the radiator to have easy bends. The petrol tank is carried under the driver's seat, so that pressure feed is unnecessary, and the lubrication is by the usual "F. I. A. T." mechanical lubricator. The change speed lever and the brake lever are both arranged on the right hand side of the driver.

Motor Tramcars for New Zealand.—The Scottish Motor Engineering Co., Ltd., of Granton Harbour, Edinburgh, are building a number of tramcars, propelled by internal combustion motors using petrol, for use in New Zealand and Australia. The motor which is a four-cylinder one developing 24 h.-p., is mounted on a bed plate, carried on the underframe of the car at one end thereof. The power of the motor is transmitted through a clutch of large diameter, thence through a special compound starting gear and gearing to one of the axles. The vehicle can be driven from both ends, but only in a forward direction, so that the driver must always be on the front platform. The control is through a detachable hand lever which has to be taken from one platform to another. The vehicle, which carries 50 passengers, is 23 ft. long overall, the platforms being 5ft. long. The weight of the vehicle unladen is just under 5 tons and is



MOTOR TRAMCAR: SCOTTISH ENGINEERING CO., LTD., EDINBURGH.

capable of ascending a gradient of 1 in 15 with a full load. The petrol and water tanks are sufficiently large to run the car 100 miles without replenishing. The petrol consumption is approximately ·1259 gallons per h.-p., per hour. These vehicles are entirely "British" made throughout and have nothing but British material and British labour in their construction. The manufacturers have succeeded in making the control as simple as possible. The driver has practically nothing to do with the engine, that is so far as having ignition and throttle levers to attend to while driving, as the engine is practically automatic from the time it is started. When pulling a light or heavy load, as the case may be, on a good flat road the engine runs very slowly, and when a gradient is met with the engine automatically works itself up to a greater speed, the maximum being 700 per minute.

Motor Vehicle for Commercial Travellers.—At the recent Motor Show at Edinburgh, Messrs. Argylls, Ltd., showed a type of vehicle for which we anticipate there will be a large demand in the near future. It is designed for the use of commercial travellers and has an enclosed body fitted with suitable shelves for carrying samples and with one or more seats. It is also proposed to add a writing table when required. The interior is well lighted by four windows, those in the front being arranged to slide so that the occupant can converse with the driver. The usual second seat is provided by the driver's seat, so that the user can travel inside or out at pleasure. If the samples are bulky they could be carried either on the roof or by dispensing with the second front seat on the footboard.

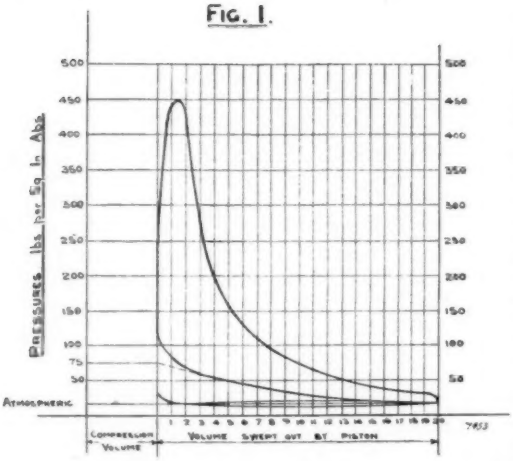
Silencers.—One of the parts of internal combustion engines to which manufacturers are now turning their special attention is the silencer or muffler. Silent running has now come to be considered such a *sine qua non* in a modern motor car, whether used for pleasure or commerce, that a complete muffling of the exhaust is imperative, and although this end can be easily attained if no heed is paid to the loss of power—due to back pressure on the exhaust—which results, it is not such an easy matter to obtain the desired result without some loss of efficiency due to this cause. Some makers claim

that their silencers not only cause no back pressure, but actually create a partial vacuum which tends to increase the efficiency of the engine. In France, where the Automobile Club have conducted two sets of trials of silencers, the most efficient apparatus in the last trial showed a loss of engine power of only 2 per cent., which may be taken as very creditable, in view of the fact that the most efficient apparatus in the 1903 trials showed a loss of over 11 per cent. of engine power.

The winner of the first prize in the last (1905) competition, which, as before stated, only produced a loss of engine power of 2 per cent., was the "Clair," which consists of a series of annular plates of thin metal, each having a series of circumferentially arranged corrugations, the outer corrugation having a series of small protuberances on its projecting face. These plates are placed in pairs—*i.e.*, with the depressions of the corrugations facing one another, against one another, the protuberances before referred to maintaining a slight distance between the plates. The plates are arranged in three groups in a cylindrical chamber, having an inlet at one end and an outlet at the other. The first and second groups are separated by a baffle plate, the diameter of which is less than that of the chamber, so that it leaves an annular space around it. The second and third groups are separated by a baffle plate of annular form, the exterior of which is the full diameter of the chamber, and the interior diameter of which is slightly less than the exterior diameter of the corrugated plates, while the end of the third group of plates is closed by a baffle plate similar to that between the first and second groups. The outside wall of the silencer is composed of sheet asbestos reinforced with a cover of perforated zinc plate. The exhaust gas entering the silencer, passes into the centre of the first group of plates, and thence outwards through the chambers formed by and between the corrugations in said plates, which by reason of their enlarged areas operate as expansion chambers. Thence it passes the reverse way through the second group of plates to the space in the centre of said plates, and thence outwards through the third group of plates around the final baffle plate, and so to the outlet.

Four *versus* Six-Cylinder Motors.—The controversy that has been raging in the automobile world, especially amongst those interested in the production of motor road vehicles, on the respective merits of four and six-cylinder internal combustion motors, seems to point, as one would expect, to the superiority of the six-cylinder engine if the question of first cost is not taken into consideration. Mr. S. F. Edge, the champion of the six-cylinder engine, has backed up his arguments by publishing a series of diagrams showing the results of some tests made with a standard 40 h.-p. six-cylinder "Napier" engine, which we produce. The deductions he draws from these diagrams may be summarised as follows:—The first consideration taken into account was the variation of pressure in the cylinder. For the purpose of ascertaining this a large number of observations were made with manograph indicator and pressure recorder. The indicator diagram shown in Fig. 1 shows a mean of these readings. The vertical line is graduated to give pressure in lbs. per square inch. From the diagram it will be noticed that the compression is carried to about 75 lbs. per square inch. The ignition takes place considerably before the end of the compression stroke, and the pressure rises very rapidly to nearly 450 lbs. per square inch. As the area of the piston is 1,256 square inches, the total pressure on each piston is roughly 2 tons. The diagram also clearly shows the fall of pressure during the working stroke and the slight rise and fall above and below the atmospheric pressure during exhaust and suction strokes. There are, however, other factors at work which this diagram does not show. For instance, at the beginning of the suction stroke the piston is being pulled along at an ever-increasing rate, while the crank travels through approximately 90 degs. Then until the end of the stroke the piston tends to keep on moving, and has to be retarded and brought to rest by the crank-shaft. In other words, the inertia of the piston and parts moving with it is retarding the crank during the first half of each stroke and urging it on during the latter half. The pressure in the cylinder and the force necessary to accelerate the piston have both been taken into account in the diagram shown in Fig. 2, which is the torque diagram for a single cylinder motor. The turning effort is given in lbs.-inches. For example, at point A. 400 lbs.-inches represent a pressure of 200 lbs. on the crank-pin tangential to the crank arm, and acting at a 2-inch radius. The thick horizontal line represents the average turning effort during the four strokes which constitute the cycle. It also shows the effort of the inertia of the piston in giving negative and positive turning efforts at the beginning and end of each stroke. At the end of the compression stroke, instead of getting a large

FIG. 1.



MEAN EFFECTIVE PRESSURE 82 LBS PER SQ INCH

CYLINDER – 4 IN BORE · 4 IN STROKE 1700 R P M

negative turning effort on account of the increased pressure in the cylinder, it will be seen that the torque has only a small negative value, thus showing that the inertia of the piston coming to rest at the top of the stroke is nearly sufficient to compress the charge; also that when the crank is on the dead centres there is no turning effort. The dotted line in the diagram shown by Fig. 3 is arrived at by superimposing four of these diagrams corresponding to four cylinders with cranks at 180 degs. The diagram shown in Fig. 4 is a torque diagram for a motor with six cylinders, one cylinder firing every 120 degs. In comparing these diagrams it must be remembered that if the cylinders are all the same size a six-cylinder engine will give approximately one-and-a-half times the power of a four-cylinder engine, and therefore in this diagram each vertical height of the dotted figure has been increased one and a half times, to the full line corresponding to larger pistons, to equalise the powers of the two engines. The most important point to be noticed is that with six-cylinders there is always a positive turning effort of at least 700 inch-lbs. on the crank-shaft, and at no point of the cycle does it approach zero. With four cylinders and cranks at 180 degs. there must of necessity be four points in the cycle, viz., when the cranks are on the dead centres, at which there can be no turning effort. The diagram shown in Fig. 3 shows also

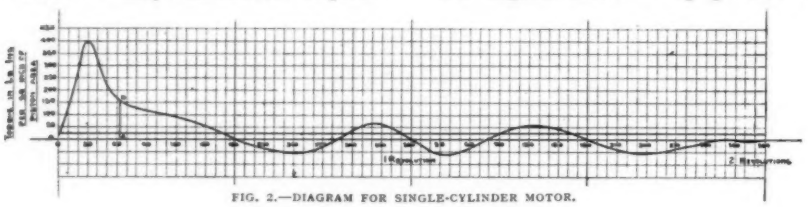


FIG. 2.—DIAGRAM FOR SINGLE-CYLINDER MOTOR.

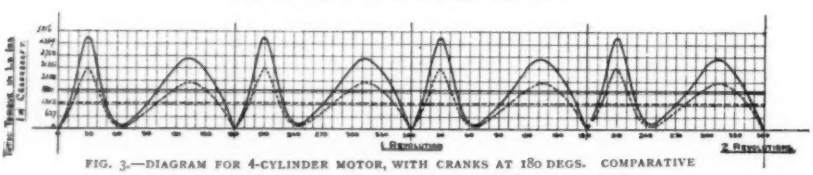


FIG. 3.—DIAGRAM FOR 4-CYLINDER MOTOR, WITH CRANKS AT 180 DEGS. COMPARATIVE DIAGRAM FOR 4-CYLINDER MOTOR OF SAME POWER AS 6-CYLINDER MOTOR.

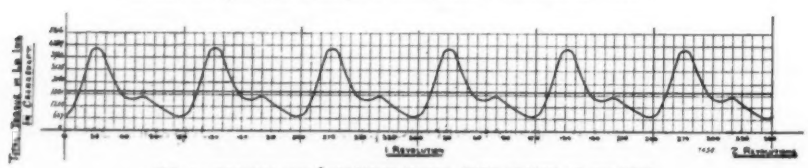


FIG. 4.—DIAGRAM FOR 6-CYLINDER MOTOR, WITH CRANKS AT 120 DEGS.

four other points, where the torque has only a very small positive value, namely, less than 300 lbs.-inches. This is accounted for by the retarding force of the pistons when being accelerated after the effect of the explosion has passed. The next rise in the torque is due to the forward pressure of the pistons when nearing the end of the stroke. One factor which has not been taken into account in the construction of these diagrams is the variation of pressures in the crank case. Obviously, the pressure behind the piston in a fast-running engine cannot remain constant. On the down-stroke it will be higher and on the up-stroke it will be lower than atmospheric pressure. The disturbing effect which this has on the torque is all in favour of the six-cylinder engine, for two reasons. Firstly, the four-cylinder engine must have larger cylinders, on which the effect will be more apparent; and secondly, in the six-cylinder engine the small effect will be reproduced six times as compared with four times that the large effect is produced in the four-cylinder engine. Mr. Edge points to the lightness of the pistons in the six-cylinder "Napier" engine, and asserts that had the pistons been heavier the positive value of the torque shown in diagram No. 3 would probably have resolved itself into one of negative value, but he omits to give such information as the weights of the "Napier" pistons and connecting-rods and the proportion of such that has been assumed to reciprocate with the piston and revolve with the crank-shaft, and also the ratio between the throw of the crank and the length of the connecting-rods. Constructive diagrams such as these fail to show the saving of piston friction and of power expended in operating the valves that must accrue in an engine having a lesser number of cylinders. What is quite clear is that the greater the number of cylinders the lighter the reciprocating parts can be made, and consequently the higher the engine speed obtainable and the quicker the engine can be accelerated, while on slow speeds the individual impulses will be less noticeable. It also follows that the driving strain, not only on every part of the engine, but also on the transmission gear and the tyres of the wheels, will be less intense, and therefore less subject to wear and tear. The crux of the whole question, therefore, is, viz., how many cylinders should be employed. If six are better than four, obviously eight are better than six. Apart from the question of the increased number of parts to look after, first cost seems to be the dominating factor.

Abstracts from the Continental Press.

Port Extensions at Genoa.—The local authorities of Genoa have decided to enlarge the port at a cost of 60,000,000 lire. A large basin will be constructed to the east of Cape Faro (which divides Genoa from the western suburb of Sampierdarema) exclusively for coal traffic. The depth will be 40 ft., the area 100 acres, and the quay space about 1,500 yards long; and the quays will be equipped with coal handling plant to cope with an annual traffic of about 4,000,000 tons, or double the existing trade. This basin will be ultimately joined by a line of docks westward along the sea front at Sampierdarema. Its construction will entail the building of a breakwater, running west from the bend in the existing Galiera mole for a distance of about 1,800 yards parallel to the shore, and an entrance to the new basin will be cut through the mole, which will also be extended for a couple of hundred yards toward the south-east to protect the mouth of the old port. The new port will be served by the San Benigno railway, and a new road will be cut round Cape Faro to connect the new basin with Sampierdarema direct. The old mole (Molo Vecchio) is to be enlarged and provided with a quay wall on the south side, together with a large waterside station to replace the old Piazza Carimento station, which is insufficient to cope with the traffic. A railway will also have to be constructed to run round the port and connect this station with the others. The Sapri mole, to the north of the Molo Nuovo, will be demolished, whilst the Carracciolo mole is to be enlarged.

With these alterations, says *Le Génie Civil*, the old, crescent-shaped port, which is nearest

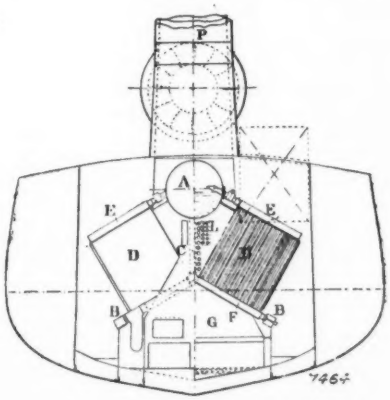


FIG. 1.—"BOROWSKY" MARINE BOILER.

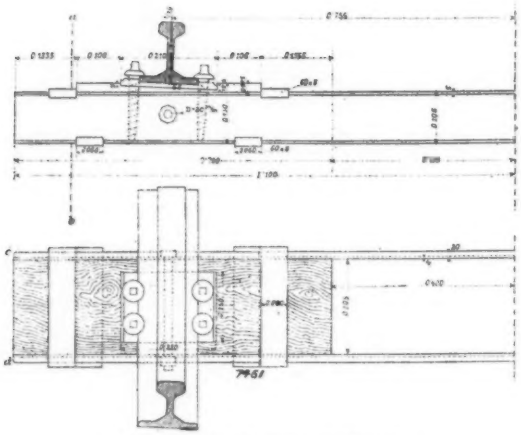


FIG. 2.—"MICHEL" COMPOSITE SLEEPER.

the business centre of the city, will deal with produce; timber, iron and textiles on the western side; grain in the centre (new silos are projected), whilst the outer port will be reserved for coast traffic.

The new quays in the outer port will be built of ferro-concrete, of the type adopted in the Manchester docks, the walls being formed of pillars, 50 ft. apart on a rock foundation, or on the bed obtained by dredging to a depth of 30 ft. below sea level. They will measure 19 ft. across the base, 11 ft. at the crown, and 42 ft. from front to back, the intermediate spaces being filled with rubble, retained at the base by a line of blocks. The quay surface will be supported by nine rows of ferro-concrete girders 56 in. high, and resting on a wall plate of ferro-concrete to secure uniform distribution of pressure.

The Borowsky Marine Boiler for Bituminous Coal or Oil Fuel.—This boiler consists of a water trunk *A*, and a double set of water-tubes *D*, mounted on each side of the firebox, together with a small rectangular trunk *B*, on either side. The tubes are arranged in sections consisting of single or double rows each communicating with the upper and lower trunks by cross tubes *E* and *F* at the top and bottom respectively; and each section can be disconnected, in the event of any of the tubes needing renewal, &c., by removing sleeve connections, whereupon self-closing valves on the fittings of the upper and lower trunks prevent any leakage. The top walls of the cross tubes *E* are fitted with screw-plugged holes for cleaning the water-tubes. The cross tubes *E* and *F* form the upper and lower wall of the tube chamber, which is bounded on the side next the central flue *L* by a wall of corrugated iron, and on the opposite side by an outer casing. The hot gases traverse the firebox *G* from front to rear, then enter the tube chambers and return to the front end, to pass thence through the central flue *L* rearward again to the funnel *P*. By this arrangement the gases do not come into contact with any extensive cold surface until complete combustion has been secured, thus preventing smoke, and their subsequent path is long enough to enable the utmost possible utilisation of their heat. An economiser, for heating the feed water and air of combustion, is arranged in the central flue *L*.

Compound Wood and Iron Sleeper.—Under the influence of the rolling load, the ballast under railway sleepers is compressed more strongly near the ends of the sleepers than in the centre of the track; and from this cause a moment of flexion is set up, which attains its maximum value underneath the rail, whilst at the same time the pounding action of the sleepers is accentuated, and this in turn reacts on the fishplates and the rail joints. In view of these considerations, M. Michel has designed the combined sleeper shown in the accompanying figures. The sleeper consists of two ⌣ irons, the ends of which grip two 28 in. lengths of wood, leaving the central part of the sleeper open for a distance of about 32 in. Each block is fastened to the girders by means of four iron clamps, fixed on by hydraulic pressure whilst warm, and a bolt is passed through the block and irons, just under the rail foot. The rails are laid on plates and held in position by spikes. Sleepers constructed on this principle have been tested by a tensile strain of 11½ tons and a pressure of 20 tons, the displacement between the wood and iron under these conditions being only one-twelfth inch. The cost per sleeper is about 3*s*. 6*d*. for the iron and 1*s*. 8*d*. for the timber, and the life of the iron is believed to be fifty years, the wood lasting about half as long. Some of these sleepers have been tried on the underground railway in Paris, under heavy traffic conditions, and are reported on favourably, both as regards stability and absence of creep, and the P.L.M. Co. is about to test 5,000 on the main line.

Accumulator Batteries as an Auxiliary in Gas-driven Power Stations.—Owing to their internal dead point, gas engines, like other explosion motors, cannot start themselves, but where accumulator batteries are used to store energy in gas-driven electrical stations, this energy can be drawn on for starting the motors. According to H. Goetze (*Centralblatt fur Accumulatoren-Technik*) it is inadvisable to employ the whole battery for this purpose, though a powerful current is

necessary, since the battery will be already under high load in supplying the lighting circuit. In the alternate method of using only part of the battery, three possibilities are available, but the best is that illustrated in the Fig. 3. The advantage of this plan is that the starting current impulse is taken from the most fully charged cells and is therefore harmless; the field magnets are excited by the full tension of the line circuit.

Mariage Automatic Catcher for Tramcars.*—M. Mariage, chief engineer to the technical department of the Paris Cie Générale des Omnibus, has devised an automatic safety apparatus involving some new features. It consists of a wooden frame *A*, connected and strengthened by sheet iron. The frame is partly supported by the grease boxes, by pivots *B*, and partly (in front) by two bars articulated on cranks on a shaft *C*, mounted on the side frames of the car. A third crank on this shaft is connected by a chain, with a catch *E*, engaging with a second catch *D*. The automatic release of the catcher is effected by a grid frame covered with piassava fibre, and pivoted on a shaft *F*, whilst two smaller auxiliary frames, a little to the rear, are connected to the front one by chains. When either of these frames strikes against a body lying across the tram lines they are forced backwards, and this movement causes a cam *G*, to release the catch *D E*, whereupon the spring attached to the catcher presses the latter into the position shown by the dotted lines, and enables it to receive the obstacle. At the same time, the catch *E*, being connected with the lifting lever *H* on the driver's platform, puts on the compressed air brake, which is controlled by the same lever, thus stopping the car. The catcher is raised by foot pressure applied to the other arm of the lever *H*. The driver can also lower the catcher by pressing with his foot on the pedal *I*, which releases the catch *D*.

Sub-river Tunnel of the Metropolitan Railway of Paris.—Dumas (*Génie Civil*) describes the construction of the tunnel under the two arms of the Seine and the Ile de la Cité. To avoid passing under the Palais de Justice and the adjacent bridges the tunnel had to be laid aslant both branches of the river. The plan adopted was that of M. L. Chagnaud, and consisted of retaining both sets of rails in one tunnel of the same dimensions as the other sections of the line (in preference to two smaller tubes). Instead of boring under the bed of the river, the method of sinking vertically by means of caissons was adopted as minimising the depth of rail level (36 ft. below water level) and the gradients

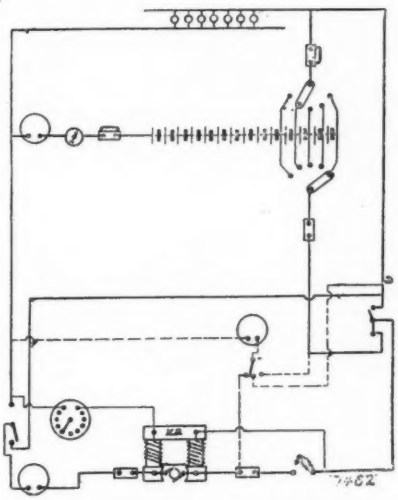


FIG. 3.—ACCUMULATORS IN GAS-DRIVEN POWER STATIONS.

at either end of the section. A cross section of the caissons is shown in Fig. 1. Here the metal tube of the tunnel is enclosed in a metal carcase and rests on the floor of the working chamber. The total height of the caissons from the cutting edges to the crown of the arch is 29½ ft. and the width 31 ft.; the working chamber presents no special features. The internal space between the tube and the outer casing is filled with cement concrete, so as to embed the iron stays and form a solid wall of ferro-concrete. Three of these caissons are required for the wider arm and two for the smaller branch of the river, the lengths in the former case being 118, 126 and 141½ ft., and 62 ft. each in the latter, all constructed on a curve of 383 yds. radius. The caisson ends

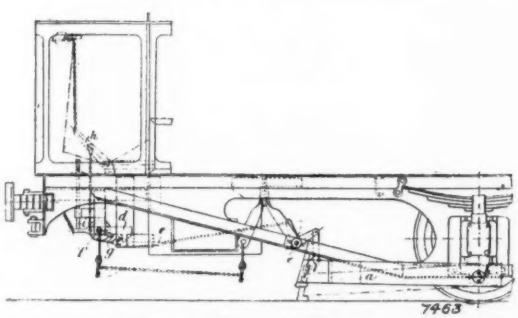


FIG. 4.—SAFETY APPLIANCE FOR TRAMCARS.

* *Génie Civil.*

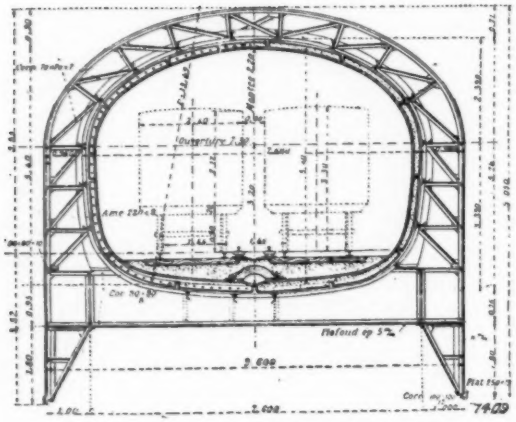


FIG. 5.—SEINE TUNNEL: CROSS SECTION OF CAISSON.

are closed with sheet metal and a space of 5 ft. is left between each pair, to be afterwards filled up by loose connecting caissons which will enable the joints to be walled and roofed in securely. The caissons were put together higher up the river and floated down to the site, which had already been deepened 16 ft. below the normal bed by dredging. The guiding piles were utilised to form scaffoldings for the working stages; and the caissons having been put in position were loaded with the tubbings for the tunnel and with the cement-concrete lining, to be then connected with the working shafts and compressed air mains. Communication with the interior of the caissons was maintained by telephone, here applied for the first time for such purpose; and the instrument on the stage was mounted in a position for the call bell to be distinctly audible at all parts of the stage. The rate of descent through the chalk averages 8—12 ins. a day.

Two stations are to be built in this section of the line, one on the north shore of the island and the other at the Place St. Michel beyond the southern arm. In each case the system of vertical sinking by caissons has been decided on, whilst the remaining part of the section will be tunnelled with a shield, that portion (205 ft.) passing under the Orleans railway being first frozen to prevent any risk of subsidence. The station caissons are shown in cross section in Fig. 6, and have the following dimensions: Length, 223 ft.; height, 41 ft.; width, 54 ft. At each end of the central caisson, forming the station proper, will be an elliptical well, 61 × 85 ft., connecting the latter with the line tunnel and forming the means of access to the station. The joints will be of masonry as in the sub-river caissons, and the caissons and wells will be concrete lined.

Hydro-Electric Station for Supplying Toulon.—In a recent issue of the *Génie Civil*, M. Caufourier describes the new hydro-electric station at Entraygues, for supplying current to Toulon and to the surrounding district. The water is taken from the river Argens about 2½ miles above the village of Vidauban, at a point where there already existed a dam for supplying a local power station and two mills. This dam has been raised 5½ ft. so as to increase the head of water. The intake is a circular opening about 9 ft. in diameter, and has a maximum capacity of 3,300 galls. It is constructed of ferro-concrete, of Grenoble cement reinforced by T-iron circles and round horizontal rods, tied at the point of intersection. The pipe was moulded on the spot in 13 ft. lengths, and no difficulty was experienced in making the curved parts. The total length is about 600 yds. About 80 yds. from the intake the pipe opens into a settling tank, which is 65 ft. in length, 26 ft. wide at the upper end, and 29½ ft. at the lower end, constructed of cement, with a sloping floor.

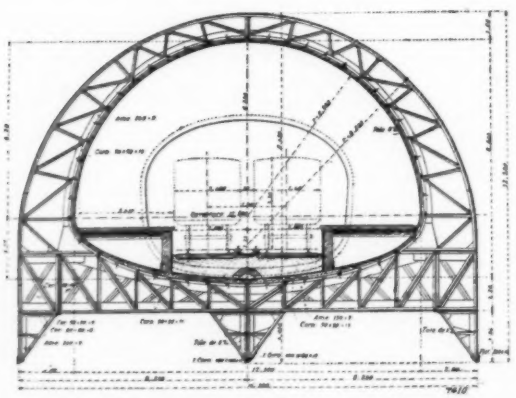


FIG. 6.—SEINE TUNNEL: CROSS SECTION OF STATION CAISSON.

At the station the ferro-concrete pipe connects with an 11 ft. steel plate distributing pipe, from which branch three 4½ ft. pipes lead to the turbines; and the main terminates in a balance pipe, consisting of two concentric pipes, the inner one (communicating with the main) 8½ ft. in diameter and open at the top, whilst the outer one, 14½ ft.

wide, is closed. Water hammer is prevented by this means, any water expelled from the mouth of the inner pipe being drained off by three 40 in. pipes draining the annular space.

The power house is protected from floods, and the turbines work under a gross head of 66 ft. The tail race is 22 ft. in diameter at the arch under the power house. There are three 1,000 h.-p. "Francis" turbines driving the alternating current dynamos, and two 75 h.-p. turbines for the excitation dynamos. The horizontal shafts of the main turbines are coupled direct to the dynamos, the coupling plates being heavy enough to act as fly-wheels. The admission is regulated by movable vanes, controlled by automatic and hand levers, the former being actuated by "Escher-Wyss" governors, in which the fluctuations of the governor bobs vary the admission of oil under pressure to a piston acting on the admission valve of the turbine. The governors can be adjusted to speeds up to 5 per cent. above and below the normal, by a small electromotor controlled from the switchboard.

The dynamos are of the "Postel-Vinay" type, 125 amperes, viz., 700 kw. amperes. The periodicity of the current is twenty-five, and the voltage 3,500. This is transformed into 28,000 volts for transmission, by three 650 kwa. transformers of the General Electric Co.; the primary is coupled in triangle, the secondary being star-coupled. The tripolar oil interrupters worked by small electromotors are beyond the switchboard, which carries only low tension apparatus, all the high tension fittings being isolated by brick partitions and inaccessible.

The high-tension cables are carried to Toulon, a distance of thirty-six miles, overhead and across country, roads being avoided as much as possible. The pine standards are about 33 ft. high and 45 yds. apart, metal standards being used at road crossings, whilst underground sheathed cables are employed where railways have to be crossed.

New Catalogues.

C. W. Hunt Co., 45 Broadway, New York. Catalogue 0511 of narrow gauge and industrial railways for handling raw and finished materials in manufacturing establishments.

Hamilton & Co., (London) Ltd., 116-118, Clerkenwell Road, E.C. 1906 List of brushes, graining tools and painters sundries.

Abner Doble Co. San Francisco, Bulletin No 7. Comprehensive catalogue entitled "Doble Tangential Water Wheels," containing matter descriptive of features and parts entering into the construction of this water-wheel and followed by descriptions of some typical hydro-electric power plants. To those interested in water power developments, this book will prove a valuable work of reference.

Large Locomotive Boilers.*

By G. J. CHURCHWARD, M.I.Mech.E.

THE modern locomotive question is principally a question of boiler. The higher temperatures incidental to the higher pressures have required the provision of much more liberal water-spaces and better provision for circulation. Locomotive engineers have now apparently settled down to the use of one of two types of boiler for very large engines, the wide fire-box extending over the frames and wheels, and the long narrow box sloping up over the axles behind the main drivers.

Much more experience has been gained with the wide box in America than in this country, and, so far as the author has been able to ascertain, it has been found there that the poorer coals in large quantities can be burnt with much greater facility and economy in this type than in the narrow pattern. This advantage is offset to some extent by the fact that, when standing there is considerable waste in the wide grates as compared with the narrow, and this is, of course, serious when goods trains are kept standing about, as is often the case here. This disadvantage has been found on the Great Western Railway, but no doubt careful design and fitting of ashpans will keep this waste within bounds.

A much more serious trouble has been found in the leaking of tubes in these boilers. This seems to be quite general, and the Master Mechanics' Association has a committee specially going into this question with a view to finding a remedy. All methods of tube-expanding have been tried, and also much wider spacing, even up to and over 1 inch, without curing the trouble. The reduction of the depth of the fire-box, in order to get a long box sloping over the trailing wheels of coupled engines, certainly increased the trouble from leakage of stays, but the alternative of a wide fire-box entails a much heavier engine for most of the types, and then apparently tube-trouble is increased. The wide fire-box evidently requires a higher standard of skill in the fireman, for unless the grate is kept well and evenly covered, there is a tendency to have an excess of air, reducing efficiency and increasing tube-trouble. With modern

* Abstract of paper read before the Institution of Mechanical Engineers, 16th February.

high pressures the temperature of evaporation is so much increased that the provision for circulation which was sufficient for the lower pressures formerly used is doubtless insufficient. Boilers in which this provision has been made have shown a very marked reduction in tube and stay-troubles.

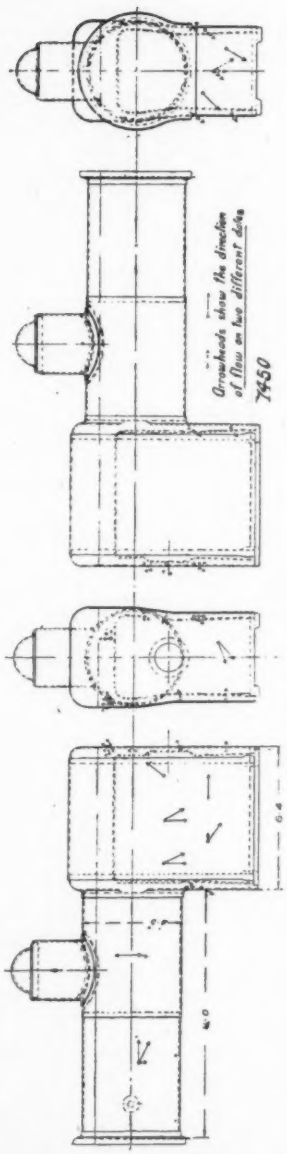
It is probable that in the wider boxes the main mass of the fire being so much nearer the tube-plate has a bad effect on the tubes, as the intensity of the temperature at the tube-plate must necessarily be much increased. The extra width of box has enabled the tubes to be put much too near the sides of the barrel. When this is done, the water to feed up the spaces between the tubes near the back tube-plate has to be drawn almost entirely from the front of the barrel, and it is possible that in some cases the space left for this purpose is inadequate. It will probably be found that neglect of this consideration is the cause of three-fourths of the tube-trouble. In several boilers designed by the author an effort has been made to provide for this upward circulation near the back tube-plate by leaving a space between the tubes and barrel from top to bottom, of a sectional area equal to the combined area of the vertical spaces between the tubes at all points, with a balance to provide for the water coming back from the front of the barrel to feed the water-spaces of the fire-box. There is no doubt that the upward draught of water through the spaces between the tubes for, say, two feet from the back tube-plate is very strong indeed, and in all probability this is enough to prevent the necessary feed of water down the spaces of the fire-box unless ample area is given, so causing stay as well as tube-trouble.

By putting the clack-box for both injectors under the barrel and providing an internal nozzle directing the feed back towards the fire-box, considerable assistance is probably given in feeding "solid" water back to the fire-box and hottest part of the tubes. It is generally supposed that the circulation in a locomotive boiler proceeds along the bottom of the barrel from the front end down the fire-box front and up the sides and back of the fire-box. The author two or three years ago fitted a number of vanes in a boiler with spindles passing through lightly packed glands to the outside, with indicators to show the direction of the flow of water. Observations showed that the circulation was generally as stated above, but a little alteration of the firing had the effect of materially changing the direction of the currents and even of completely reversing them. The accompanying illustration is submitted to enable the results of this experiment to be appreciated. The arrows show the different directions of the currents in the various experiments.

These experiments suggested the desirability of bringing a circulating pipe from the front of the barrel, bifurcated to each side of the fire-box at the foundation ring, but the consideration of possible danger from an outside pipe open to the boiler, caused the experiments to be abandoned. The experiment has since been made in America, and it is reported that great reduction of trouble with slide sheets resulted. The extended length of tubes seen in some designs of wide fire-box boilers is due to the use of 6-coupled wheels in front of the fire-box. Experience of long tubes appears to be quite satisfactory, and they certainly keep up the economical efficiency of the boiler when it is being forced to the limit of its capacity. In this respect the long tube fulfils the same function as the "Serve" tube performs in boilers with shorter barrels.

The ratio of diameter to length of the tube undoubtedly has a most important bearing upon the steaming qualities of the boiler and upon the efficiency of the heat absorption. This is more particularly noticeable when the boilers are being worked to the limit of their capacity. If 2-inch tubes, say, are employed in barrels 11 to 12 feet long, when the boiler is being forced the length is not sufficient to absorb the heat from the amount of gases that a 2-inch tube will pass, and overheating and waste result. The amount of tube-leaking, which is experienced with modern wide boxes in America, has brought up again the idea that the spacing should be wider, say 1 inch instead of $\frac{3}{4}$ inch; but, from the investigations of a Master Mechanics' Committee, it appears that the wider spacing does not cure the trouble. It is clearly of no use to provide wider spaces for the upward current, unless equivalent area is provided for the downcoming water.

The gradual extension of the practice of making the top of the fire-box and casing flat instead of round is noticeable. On the Great Western Railway less trouble has been experienced with the flat top fire-box than with the round top, although no sling-stays of any kind are used. The flat top has the important advantage of increasing the area of the water line at the hottest part of the boiler, and so materially contributes to the reduction of foaming. This, combined with the coned connection to the



CIRCULATION OF WATER WITH TWO DIFFERENT METHODS OF FIRING.

barrel, has enabled the dome, always a source of weakness, to be entirely dispensed with and drier steam obtained. The author some years ago made an experiment to settle this much-disputed point. Two identical engines and boilers were taken, one boiler having a dome in the usual position on the barrel, the other having no dome, the steam being taken by a pipe from the top of the flat fire-box casing. The engine without the dome proved to be decidedly freer from priming than the other. The liberal dimension of 2 feet between the top of the fire-box and the inside of the casing no doubt contributed to this satisfactory result. The coned barrel connection, in addition to providing a greater area of water line, also gives a larger steam capacity, and, by the larger diameter being arranged to coincide with the line of the fire-box tube-plate, much more water-space at the sides of the tubes is possible. On consideration of the great intensity of temperature at the fire-box plate as compared with that at the smoke-box plate, the advantage of the arrangement is obvious.

The employment of a superheater is having an extended trial in Germany and also in Canada. This affords the prospect of obtaining the same steam efficiency by the use of, say, 175 lbs. pressure, as by employing the pressures of, say, 200 lbs. to 225 lbs. This, no doubt, offers some prospect of success, and is attractive from the fact that the alternative of compounding necessitates the use of the higher pressures and consequently presents no hope of relief from boiler troubles.

An examination of the ratios will show how much more heating surface is now provided for a given area of cylinder than used to be considered necessary. The higher pressures now common have undoubtedly produced much more efficient locomotives, both in respect of hauling power and coal consumption. This improvement has been very marked with every increment of pressure, right up to 227 lbs. carried by the "De Glehn" compounds. These have been most successful compounds, and the high pressure carried is no doubt an important factor. By employing 225 lbs. per square inch in the simple engine, and making the necessary improvements in the steam distribution, enabling higher cut-offs to be used, corresponding improvements in efficiency and economy of fuel have been obtained. Great increase in the draw-bar pulls at high speed has also resulted. Of course, the price for these improvements has to be

paid in the matter of fire-box repairs and renewals, but it is probably better to submit to this expense than to employ the very much heavier and more costly machines which would be necessary to give the same hauling power at speed.

The Electric Production of Nitrates from the Atmosphere.

As the demand of the white races for wheat as a food-stuff increases, the acreage devoted to wheat growing increases, but at a less rapid rate; and being limited by climatic conditions will, in a few years, perhaps less than thirty, be entirely taken up. Then, as Sir William Crookes pointed out in his presidential address in 1898, there will be a wheat famine, unless the world's yield per acre (at present about 12·7 bushels per acre on the average) can be raised by use of fertilisers. Of such fertilisers the chief is nitrate of soda, exported from the nitre beds in Chili. The demand for this has risen from 1,000,000 tons in 1892 to 1,543,120 tons in 1905, and the supply will at the present rate be exhausted in less than fifty years. Then the only chance of averting starvation lies, as Crookes pointed out, through the laboratory.

In 1781, Cavendish had observed that nitrogen, which exists in illimitable quantities in the air, can be caused to enter into combination with oxygen, and later he showed that nitrous fumes could be produced by passing electric sparks through air. Although this laboratory experiment had undoubtedly pointed the way, though the chemistry of the arc flame had been investigated in 1880 by Dewar, and though Crookes and Lord Rayleigh had both employed electric discharges to cause nitrogen and oxygen to enter into combination, no commercial process had been found practical for the synthesis of nitrates from the air until recently.

In a lecture recently delivered at the Royal Institution by Professor Silvanus P. Thompson, F.R.S., and reported in abstract in *Nature*, attention was directed to the process of Birkeland and Eyde, of Christiania, for the fixation of atmospheric nitrogen, and their synthetic production of nitrates, by use of a special electric furnace. In this furnace an alternating electric arc was produced at between 3,000 and 4,000 volts, but under special conditions which resulted from the researches of Prof. Birkeland, the arc being formed between the poles of a large electromagnet, which forced it to take the form of a roaring disc of flame. Such a disc of flame was shown in the lecture theatre by a model apparatus sent from Christiania. In the furnaces, as used in Norway, the disc of flame was 4 ft. or 5 ft. in diameter, and was enclosed in a metal envelope lined with firebrick. Through this furnace air was blown, and emerged charged with nitric oxide fumes. These fumes were collected, allowed time further to oxidise, then absorbed in water-towers or in quicklime, nitric acid and nitrate of lime being the products. The research station near Arendal was described, also the factory at Notodden, in the Hitterdal, where electric power to the extent of 1,500 kilowatts was already taken from the Tinnfoss waterfall for the production of nitrate of lime. This product in several forms, including a basic nitrate, was known as Norwegian saltpetre. Experiment had shown that it was equally good as a fertiliser with Chili saltpetre, and the lime in it was of special advantage for certain soils. The yield of product in these furnaces was most satisfactory, and the factory at Notodden—which had been in commercial operation since the spring of 1905—was about to be enlarged; the neighbouring waterfall of Svaelgfos being now in course of utilisation would furnish 23,000 h.-p. The Norwegian company had further projects in hand for the utilisation of three other waterfalls, including the Rjukanfos, the most considerable fall in Telemarken, which would yield more than 200,000 h.-p. According to the statement of Prof. Otto Witt, the yield of the Birkeland-Eyde furnaces was more than 500 kilograms of nitric acid per year for every kilowatt of power. The conditions in Norway were exceptionally good for the furnishing of power at exceedingly low rates. Hence the new product could compete with Chili saltpetre on the market, and would become every year more valuable as the demand for nitrates increased, and the natural supplies became exhausted.

A New Machine for Bending Tests.

THERE is at the present time in work, at the Swiss Technical Institute, a new type of testing machine which combines unusual simplicity and precision, with a number of other advantages not possessed by other machines for bending tests.

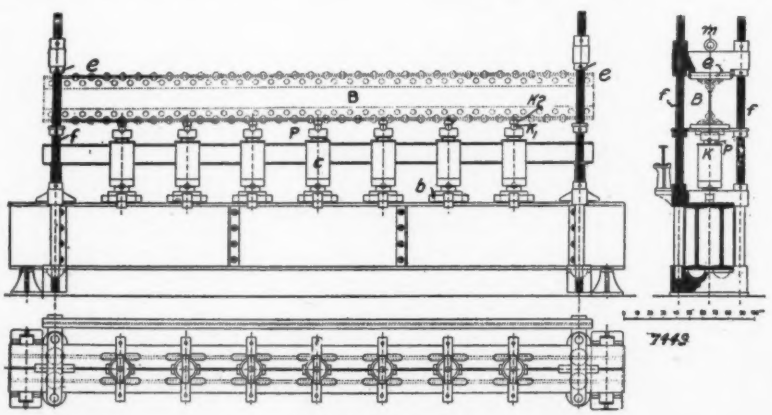
It was designed in connection with the working out of the Swiss standards for concrete and armoured-concrete, as it was found that the work of the commission was hampered by their inability to obtain accurate results with other machines.

The most important parts of this machine are schematically illustrated in the drawing, for which we are indebted to the *Engineering Record*, New York.

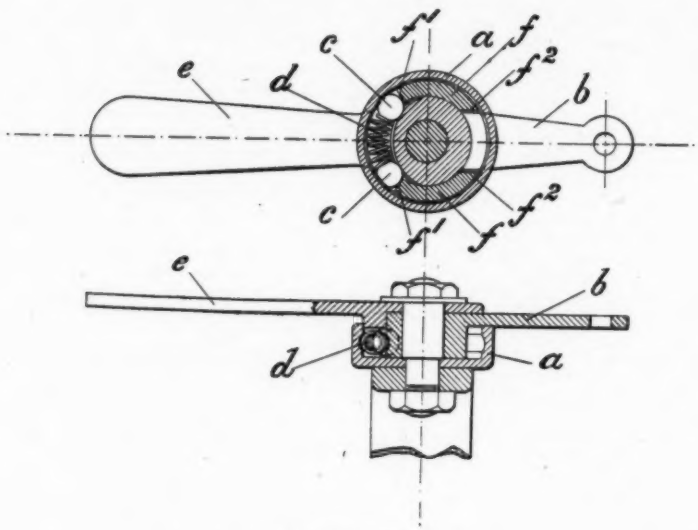
The load is applied by seven pistons, with a variable distance from centre to centre, but 50 cm. is usually advantageous, as in the experiments at the Institute. In this manner the equally distributed load per running metre is obtained by doubling the load working in one point. Pistons without friction are used for loading. Every press is provided at the bottom with a steel sphere; above are two tipping pieces, k_1 and k_2. It is evident that each cylinder c will only exert a force along its axis, but that there is no side support of the beam under experiment at the point of contact with the load. By raising the load the beam is therefore assigned to its own stiffness against breaking on the side. The presses p are driven with Ricinus oil. Before the commencement of the experiment the pistons k must be placed exactly vertical, which is made possible by each cylinder possessing underneath four bolts, b, fitted with spiral springs. A pump driven by hand or motor and connected by pipes with the separate cylinders causes the raising and sinking of the pistons. The load is read off from scales, by means of mercury columns. Each machine possesses two scales, one up to 3 tons, the other to 18 tons per press, so that a load of 126 tons can be produced by this machine.

The beams are supported on the edges, e, which are fitted in frames, which in its turn swings on its lowest part, with the result that the changes of strain in the fibers, supported at the ends, remain without influence on the inner strains.

The beam B to be tested is placed with great accuracy in such a position that all the forces can work exactly in the centre plane, M, of the beam. Unless this is carried out with great precision, the fault is noticeable shortly after the commencement of the loading in the distortion of the beam. After placing the beam in position on the cylinders, c, the axis of the body will fall in a vertical plane with that of the cylinders. The centre line of the two edges must also fall in this vertical plane. Instruments for measuring the bending are applied in the middle and at both ends, and the actual bending in the middle is the difference of the middle reading and the arithmetical mean of the readings at the two points of support. The other arrangements for measuring the strains in certain parts of the beam are the same as for other machines.



BENDING TEST MACHINE.



NOVEL LOCKING BEARING. 2071

By raising the pistons, which are controlled according to a scale, the load is brought into action. The experiment can be carried on so far that a very large bending takes place. Absolute breaking is very seldom done by the machine; but this is quite irrelevant in beams under the influence of bending, since the question is to discover the stiffness of the beam and not the breaking-point. By laying the beam on the pistons, without laying it upon the edges, the weight of the beam may be determined with a fair degree of accuracy, a distinct advantage when large, heavy beams are in use.

This machine is as applicable in practice as well as in the laboratories, and has the great advantage that bodies of large dimensions can be tested, and that the load can be made to rise and fall in rapid succession, which is specially useful in determining the changes of strain by often repeated loading. The equal distribution of the load over the whole length of the beam by the pistons results in the deformations and changes of strain of the whole body being readily seen, a fact of special importance in the testing of reinforced concrete.

A Novel Locking-Bearing.

THE accompanying illustration refers to a neat mechanical device recently put on the market under the title of "Autoloc" which may be used as a lock, hinge, or lever, or to replace certain apparatus hitherto involving the use of a ratchet, notched quadrants and bars, or triggers and pawls. A further feature is that the apparatus provides an efficient substitute in many cases where worm gearing has hitherto been utilised to obtain an irreversible lock, or where clamping devices have been resorted to. Briefly the invention consists of a device for immovably locking together any two members of a rotating or sliding mechanism, in such manner, that relative movement is rendered impossible by force applied to either of those members, whilst provision is made for obtaining relative movement by the application of small force in either direction to a third member.

The adjustment of movement between the two parts forming the turning or sliding pair, may be made as large or as small as may be desirable, whilst there can be no backlash in the mechanism.

The illustration shows the apparatus applied to a lever for controlling the

throttle or ignition adjustment of an internal combustion engine. The lever *b* may be set in either direction by the manipulation of the hand lever *e*, but as soon as the latter is released, the lever *b* remains locked. The locking device consists essentially of two balls *C C* lying in an annular space formed between the locking lever *b* and the cup *a*. The space is so formed as to diminish in width from the centre outwards in both directions, and the balls are separated by a spring *d* which pushes them apart and into close contact with the interior surface of the cup and the exterior cam surface of the lever *b*. This arrangement forms a dead lock if force be applied to turn the lever *b* on its axis in either direction.

In order to manipulate the lever when desirable, the operating lever *e* is mounted on the same axis as the locking lever *b*, and provided with lugs *f f* which enter the cup and have faces f^1 f^1 which lie in close proximity to the locking balls and other faces f^2 f^2 on either side of the locking lever.

The clearance between the faces f^1 f^1 and the balls is very little, and is made somewhat less than the clearance between the faces f^2 f^2 and the locking lever.

The effect of movement communicated to the lever *e* is as follows, and is similar in whichever direction the movement takes place.

One of the faces f^1 comes into contact with the hindmost ball (according to the sense of direction of the movement), and slightly compressing the spring *d*, pushes the ball out of simultaneous contact with the walls of the cup *a* and locking lever *b*, which form the double tapering recess, until the face f^2 reaches the arm of the locking lever *b* with which it engages, imparting its movement directly thereto, the foremost ball meanwhile rolling back in the recess, or, in other words, free wheeling. Directly the actuating force is withdrawn the spring *d* pushes the balls tightly into the tapering portions of the recess and so locks the lever *b* immovably in the cup *a*.

The interior surface of the cup and the cam surface of the locking lever are grooved to fit the contour of the balls, thus guarding against pitting of the ball races, whilst any wear in the balls or the ball races is automatically taken up by the spring pushing the balls further into the taper recesses.

The apparatus is manufactured by the Finchley Motor and Engineering Co., Limited, Finchley.

Electrical Developments in Collieries.

An interesting adaptation of the regenerative principle is now being used with great success on colliery work by the Ilgner system, when hoisting or lowering the cages into the pits. This system was dealt with by Mr. G. F. Metzger, M.Inst.C.E., in the course of an interesting paper recently read before the Manchester Association of Engineers. It must be remembered that when hoisting gear is driven electrically, either from the colliery's own generating station or from a power company station, rushes of current and consequent fluctuations in the line must be avoided. These difficulties are satisfactorily met by running a motor coupled direct through a heavy flywheel from the main dynamo. The hoisting motor is a shunt wound machine, whilst the generator is separately excited to obtain the full range of voltage. When commencing the hoist the exciting current of the generator is reduced, and the torque being proportional to the current, and the voltage being at zero when starting, the motor current is at a maximum. The excitation of the generator is increased gradually, which raises the E.M.F., but decreases the amperes on the hoisting motor, as the cycle of raising or lowering the cages proceeds, thus keeping the total energy constant. The heavy flywheel, which is the secret of success on this system, is designed of suitable dimensions to enable it to store or give out the compensating kinetic energy, which the circumstances demand. Perfection in design, the author stated, has insured this being done to the exact amount required, and so that the output of the motor driving the generator remains constant.

When one cage is approaching the top of the shaft the second cage is nearing the bottom and the impetus of the motion (especially if the cages are unbalanced), together with the stored energy of the flywheel, converts the shunt wound hoisting motor into a generator, and by reducing the exciting current of the generator, thus causing its E.M.F. to drop, while that of the motor has remained constant, the action of regeneration is not only an efficient brake through the retarding effect, but returns current through the motor generator (now converted into a generator motor) into the source of supply.

In the case of a failure of current from the main source, the stored energy is found sufficient to complete the hoist.

According to Mr. Metzger, electric traction and haulage alone in a mine has not only doubled its output, but reduced the cost (as compared with horse haulage) from $4\frac{1}{2}d.$ to $\frac{1}{2}d.$ per ton. It has been found that the whole of the capital expended on the electric conversion of a coal mine was repaid in about three years by the various economies introduced and other advantages realised.

A Large Steel Ingot.

THE largest steel ingot hitherto produced was cast last month at the Manchester works of Messrs. Armstrong, Whitworth & Co. This ingot with the weight of 120 tons was made in accordance with the Whitworth fluid pressure system, the molten metal being poured into a mould itself weighing about 180 tons, which was then placed beneath a hydraulic press having a 6 ft. diameter ram working at a pressure of 3 tons per square inch. The ingot is intended for the turbines of the new Cunard liner which will develop 70,000 h.p. It is interesting to compare this enormous body of solid metal with the tiny blooms of some three-quarters of a hundredweight which represented the maximum weight of wrought iron producible in a single mass by ironworks half a century ago.

A Petrol Rock Drill.

THE latest application of the petrol engine is in connection with rock-drilling and other cutting work, Messrs. H. E. Worsop & Co., of Nottingham, having developed a rock-drill of neat design, in which this form of motive power has been utilised. The crank shaft of the motor carries a pinion which gears into a spur-wheel mounted underneath the engine. On this spur-wheel shaft is a cam engaging two bell-crank levers, which, by means of studs and collars, operate the drill-spindle carrying the jumper. The weight of the machine complete, with its cradle, is only 180 lb., and the stroke of the drill is $4\frac{1}{2}$ in. with 350 strokes per minute.

A hand tank accommodates sufficient petrol to run the drill for eight hours; the same tank also contains the batteries for ignition, the wires from which are carried in a metallic hose, which also conveys the vaporised petrol to the motor.

Resistance of Tubes to Collapse.

FOR the purpose of calculations relative to the collapsing strength of boiler and other tubes, the empirical formula deduced from Fairbairn's series of experiments, made some fifty years ago for the Royal Society and the British Association, are generally used in some form or other. The formula is:—$p = 806{,}300\ (t^{2.19} \div ld)$, where p = external pressure in pounds per square inch, t = thickness of the tube in inches, l = length in feet, and d = diameter in inches. Examination of this equation shows that it is only true for limited lengths, as the collapsing pressure cannot decrease indefinitely with the increase of length. Professor Unwin and others have endeavoured to deduce more satisfactory formulæ from the same series of experiments, but without much success. More recently the problem was considered from a purely theoretical standpoint by Messrs. G. H. Bryan, A. B. Bassett, and A. E. H. Love, the separately expressed views of these mathematicians being in substantial agreement. Mr. Love propounded the following rule:—That no tube however long can collapse unless the pressure exceeds $2E \div [(1 - \sigma^2)\ h^3 \div a^3]$, and that when the pressure exceeds this limit the tube will collapse if its length exceeds a certain multiple of the mean proportional between the diameter and the thickness. In the above expression E = modulus of elasticity, σ = Poisson's ratio, h = half the thickness of the tube, and a = the radius of the middle surface of the tube. Until quite recently no practical tests of this theoretical deduction have been conducted. In a paper read before the American Physical Society, however, Mr. A. P. Carman describes a series of experiments undertaken to inquire into the formula of Fairbairn, and examination of the results had the effect of throwing valuable light upon the type of formula proposed by Messrs. Bryan, Bassett, and Love. While showing that Fairbairn's rule was generally accurate within narrow limits, the results demonstrated its insufficiency, and suggested that the tubes tested by Fairbairn were all of less than the critical length. On the other hand, the results indicated that for tubes of greater length a formula of the kind proposed by Messrs. Bryan, Bassett and Love was more nearly true. The experiments to which we refer were made upon seamless brass tubes of small diameters, and the results are not to

250 FT. SPAN, CALUMWELLA BRIDGE, BENGUELA RAILWAY.

be accepted as entirely conclusive. Therefore it is satisfactory to learn that arrangements are being made to conduct further experiments upon steel tubes of large diameter, with the object of avoiding errors due to differences in the annealing and other treatment of small tubes, and of further testing the practicability of the more recent type of formula.

Calumwella Bridge: Benguela Railway.

THE bridge illustrated herewith was constructed by Messrs. Arrol's Bridge and Roof Co., Ltd., of Glasgow, in 1905, for the Benguela Railway contract to the order of Messrs. Pauling & Co., Ltd., the engineers being Sir Douglas Fox and partners.

It is a single line through span for the 3 ft. 6 in. gauge. The span is 250 ft., and the main girders, which are placed at 18 ft. centres, are of the "Whipple Murphy" type, 26 ft. 10 in. deep.

The floor system consists of cross girders hung below the main girders with continuous rail bearers, on the top of which rests a system of pressed steel cross sleepers, to which the rails and guard rails are bolted direct with clip washers. The rails are of the standard flat bottomed type, 60 lbs. per yard, and a footway 4 ft. 4 ins. wide, with channel kerb, and tube handrail is also provided on each side.

The bridge was constructed, erected complete in the builders' yard, and shipped in twelve weeks from the date of order; its total weight is about 275 tons.

Vacuum Tube Lighting.

SOME good examples of the vacuum tube system of lighting can be seen operating in business premises along Broadway, New York, notably at the office of *The New York World*, which is illuminated by one tube 86 ft. long running round the office, and fixed beneath the ceiling cornice: lighting tubes of this class are in operation up to 155 ft. long. They are operated by extra

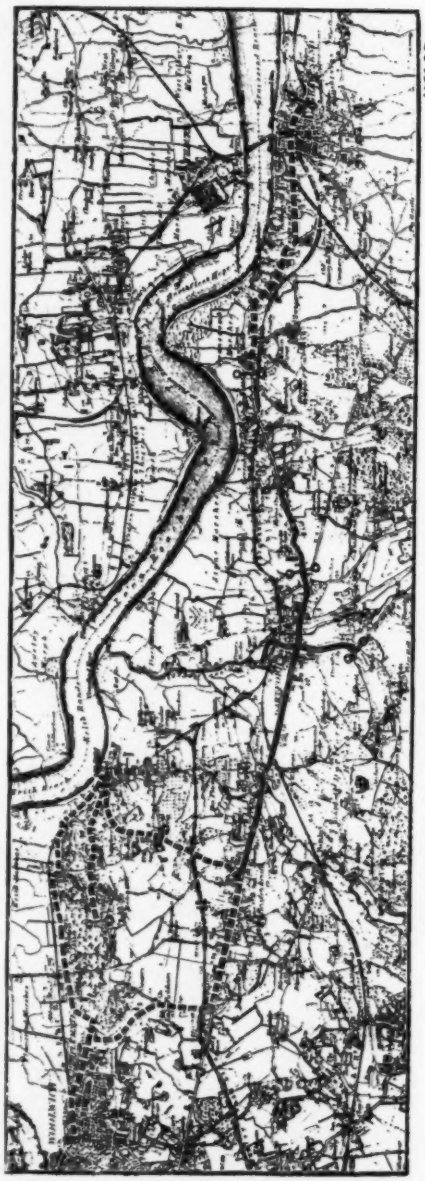
high pressure alternating current, ranging from 5,000 volts upwards, produced by a transformer enclosed in an earthed metal box; the light produced is soft and agreeable, and is a near imitation of daylight. The intensity of light can be regulated from a faint glow to twenty or more candles per foot of tube, which tubes are about 1¾ins. diameter. The illuminated tube can be looked at without inconvenience to the eye, and it appears as though it were a long cylinder of densely white smoke. The light radiating from such a large surface area gives a very perfect diffusion, and a practically "shadowless light" result. No mercury is used in these tubes, and the makers claim an efficiency as high as 1½ watts per candle, including transformer loss, and state that the life of the tubes is "almost unlimited."

Very little information is available about this form of lighting. Mr. Geo. Wilkinson, M.I.E.E., in a paper on "Waste in Incandescent Electric Lighting," read before the Leeds local section of the Institute of Electrical Engineers, states that he is unable to find that there are any of these lamps in Great Britain, but the American examples are strikingly effective, and the method is worthy of more attention than it obtains at present. Probably the ultimate form of electric lighting will be by means of incandescent vapour, of which the well-known Mercury Vapour Lamp forms an unsatisfactory and crude example.

Dartford Tramways.

THE light railway system of the Dartford Urban District Council, which was opened for traffic last month by Mr. J. Lawrence Mitchell, the chairman of the district council, runs through the centre of the town of Dartford, and connects up with the existing tramways of the Bexley Urban District Council, and by a junction with the Bexley tramways, with the existing Erith system. The London County Council tramways at Woolwich are thus brought into connection with the new system on the west, while on the east, a distance of only 1½ miles separates the terminus at Harris's Cross from the Gravesend and Northfleet tramways. It was due to the opposition of the South Eastern and Chatham Co. that this short connecting length could not be carried out.

The line, which is constructed on the overhead principle, has a mileage of 6 miles



3 furlongs, and is mostly single track with turnouts. Excepting one short gradient of 1 in 12, two of 1 in 13½ and 1 in 15½, the gradients are comparatively light. The total capital cost amounts to approximately £93,000. The permanent way and equipment calls for no further remark than that it represents standard practice. The chief contractors were Messrs. J. G. White & Co., who are also the lessees for a period of fifteen years, the lease being terminable at the expiration of five or ten years at the option of the Council.

Catalogues Received.

Recorders, Ltd., 17, Queen Victoria Street, E.C. Booklet entitled "A System that Swells Profits," the object of which is to give a simple system of dealing with jobs in the shops, so that loss of time entailed by the old method is avoided. The system consists in the employment of the Rochester Card Recorder, by which the time actually spent by the men in their own department under supervision is recorded.

Speaker and Mandorff, 29, Mincing Lane, E.C. Catalogue of "Eternit" roofing slates. Eternit is an abesto cement material and forms an effective substitute for galvanised iron or slates in tropical countries by reason of its insulating qualities. It also resists the attack of white-ants and is quite non-combustible.

Chas. Burrell & Sons, Ltd., Thetford. Leaflet descriptive of steam tractors, a speciality of this firm. They are made either single cylinder or compound, and in two sizes, 4 and 5 tons weight respectively. Constructed on traction engine lines, they are mounted on springs fore and aft: both gear wheels are driven by separate pinions from the countershaft and a specially designed steering gear is fitted, as is also an arrangement for instantaneously locking to compensating gear from the foot-plate.

Peter McIntosh & Sons, 129, Stockwell Street, Glasgow. Sectional catalogue of laminated leather belting. It is claimed that this speciality has more grip and adhesive power than ordinary belting by the fact that the leather is run on edge instead of the grain or flesh side.

William Butler, 20, Crosby Road, Birkdale. Booklet descriptive of patent camera stand which should prove invaluable in engineering workshops, enabling the operator to place the camera in any position, and fix it there without resorting to the use of a swing back or front, or to any other forms of independent attachments.

Crompton & Co., Ltd., London Wall, E.C. List V. 12 of electrical pyrometers (direct reading), for annealing and case hardening ovens, gas and steam plants, furnace and flue gases, &c. The list, which is well illustrated, is of great interest, and the principle of the instrument is lucidly set forth.

Edward C. Herbert, Ltd., Manchester. Catalogue of metal sawing machines, machine tool accessories, cramps, packings, angle plates, &c.

Electrical Notes.

By ANDREW STEWART, A.M.I.E.E.

The Production of Iron and Steel in the Electric Furnace.—Owing to the absence of large supplies of cheap water-power, we in this country have not had an opportunity of witnessing the electro-metallurgical developments which have taken place on the Continent and in the United States of America, where water-powers which may not be economical for factory purposes are practicable when used for metallurgical purposes where the load is more or less continuous during the twenty-four hours.

In many cases a water-power plant of given capacity is so expensive that the fixed charges become as great or greater than the cost of fuel and fixed charges of a steam station, but a similar water-power plant would, if working on a more or less continuous load throughout the twenty-four hours, prove economical, for not only would the fixed charges per horse-power hour be nearly one-third, but the total labour charges would only increase to the extent of the cost of another shift. In the case of a steam station, not only is a larger amount of labour necessary to work the plant, but the fuel costs increase more or less in proportion to the load and time the plant is in operation. Perhaps the only kind of equipment which in this country would economically replace the large water-power schemes of our foreign rivals would be a gas plant, where every possible advantage is taken of the value of the bye products, and during the last few years there have been some developments in this direction by chemical manufacturers wishing to develop electro-chemical operations. Electro-metallurgy has, however, developed slowly. Nevertheless, this branch of applied electricity is passing through an evolutionary process which may ultimately place the production of iron and steel by electrical processes within the range of practicability, especially if developed by large gas plants at points where not only fuel is cheap, but abundant supplies of ore at low cost are available.

The magnitude of the processes in which the electric furnace plays an important part will be readily grasped when one takes into consideration the fact that all over the world something approaching 700,000 h.-p. is used for electric furnaces. Nearly half of all the output of the Niagara power companies is supplied to firms using the electric furnace

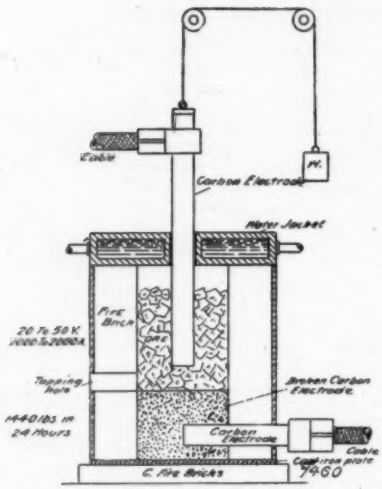


FIG. I.—EXPERIMENTAL ELECTRIC FURNACE.

for the production of such materials as aluminium, carborundum, calcium carbide, sodium, and sodium peroxide.

For some considerable time past experiments in the production of iron and steel by means of the electric furnace have been made on the Continent and in the United States. Furnaces of the arc type have been largely employed in preference to those of the resistance type, as they not only give higher efficiency, but are less dependent upon the nature and conductivity of the charge.

A series of experiments have recently been carried out at Portland, Oregon, U.S.A., with two arc furnaces reducing magnetic iron ore to steel, which seems to indicate the possibility of such a method of reduction competing successfully with the blast, and open hearth steel furnaces. For the information of those of our readers who wish to investigate the subject for themselves, the following description of the small experimental furnace used will prove useful. Fig. 1 shows this furnace in section, from which it will be apparent that the materials used were such as can be obtained in any foundry. The foundation consists of a cast-iron plate, 3 ft. × 3 ft. × $\frac{5}{8}$ in., laid on a course of fire-brick; on the top was placed an oval drum of sheet-iron about ·05 in. thick, having a height of 3 ft. The inside of this drum was lined with fire-brick, forming a crucible 24 in. deep by 18 in. wide; the bottom of the crucible, from the tapping-hole to the cast-iron plate, being filled with a broken carbon electrode, forming one pole of the furnace. The top was covered with a hollow wrought-iron cover, through which water passed to keep it cool, and in the centre of which was a hole sufficiently large to permit of the upper carbon electrode passing freely, this electrode being slung in the manner indicated.

With 1,000 amperes at 57 volts, obtained from an ordinary alternating current supply system by means of a transformer, and a charge of 390 lbs., 79 per cent. of which was magnetic ore, 90 lbs. of steel, and 200 lbs. of slag was tapped off in two hours, equal to about 3,750 h.-p. hours per ton of steel, a figure which is pretty much in agreement with figures obtained on the continent of Europe, where several experimenters have been working at the problem for some time past, and results such as are given in Table I. have been obtained.

The iron ore fed into the furnace had the following analysis :—

Fe_3O_4	79·06
TiO_2	16·0
MnO_2	2·45
Silica, moisture and undetermined matter	2·49

The charge was made up as follows : iron ore, 300 lbs.; coke, 60 lbs.; limestone, 30 lbs.; total, 390 lbs.

The table shows that, with electrical energy at a price of about $\frac{1}{4}d.$ per unit, the

TABLE I.—RESULTS OF EXPERIMENTS WITH ELECTRIC FURNACES PRODUCING STEEL.

Furnace.	Horse-power hours per Ton of Steel.	Cost (Actual).	Power Cost with Electrical Energy at $\frac{1}{4}d.$ per Unit.	Raw Material.
		£	£ per ton.	
Experimental Furnace	3,750	—	2·9	Magnetic ore.
" " "	2,240	—	1·9	" "
" " "	7,800	—	6·1	" "
Heroult	3,600	—	2·75	Iron ore
Keller	3,800	3·6	3·1	Iron ore and cast iron
Stassano	3,800	3·75	3·1	High grade Italian ore
Gysinge	1,320	8·5	1·03	Cast and wrought iron

production of steel in the electric furnace, on a commercial scale, while not commercially practicable, may come into use for the direct production of certain classes of high-grade steel.

If the statements of the promoters of the larger electric power schemes are to be taken as reasonably accurate, it does not appear unreasonable to expect that electric power can be supplied on a twenty-four hour basis for electro-metallurgical purposes at half the figure named, especially if the steel works be situated close to the electric supply station, and the expensive transmission cables thereby reduced to a minimum. We may then see an electric steel works built alongside a large electric power station, just as to-day we see chemical works alongside blast furnaces.

A larger experimental furnace capable of taking a charge of a ton was subsequently built, the same construction was adopted, except that two electrodes are employed, and currents of the order of 2,000 amperes at a pressure of 75 to 90 volts were used. Results similar to those detailed in Table I. for the small furnace were obtained, though experience with still larger furnaces seems to indicate an improvement in efficiency with increase in size. Much also depends upon the nature of the charge.

The "Heroult" furnace, mentioned in Table I., is a type of furnace which has been developed to a very practical stage. It is shown in Fig. 2, where the bottom of the furnace consists of rammed basic material, having a pouring spout at *A*. The roof *H* consists of silica bricks. The electrode *E* is one of two which form the poles of the furnace, the other being behind that shown.

One feature of this furnace is the fact that the current may be switched on and left unattended till reduction is complete, as the motor *P* can be arranged to act through the pinion *S* and rack *R*, so that it raises and lowers the electrodes with changes in the resistance of the furnace, thereby automatically keeping the current constant, otherwise the current will vary.

The "Keller" furnace is of the resistance type and is shown in Fig. 3, where the large carbon electrodes are shown at *A* and *B*, these make contact with the charge which consists of Swedish pig or pig and ore. The current passes from one electrode to the other through the material to be reduced, and the two furnaces are not at first in electrical contact, except through a heavy conductor. As the reduction proceeds the space between the two furnaces becomes filled with molten metal which is kept at a high temperature by the auxiliary electrode *C*, this furnace being in reality a two-stage furnace where the first reduction takes place in the larger furnaces, and the molten metal is acted upon by the current passing in by the electrode *C*, in what is really a steel furnace from which the metal is tapped off as desired. The results obtained with this type of furnace in northern Italy seem to indicate that it is among the best type of resistance furnace yet produced. Table II. shows the cost of a ton of steel, the electrical energy being supplied from a waterfall at a cost of about 0·16 pence per unit on a twenty-four hours' basis.

TABLE II.—COST OF ONE TON OF ELECTRICALLY PRODUCED STEEL.

	£	s.	d.
Ore, 55 per cent. iron... ...	0	8	0
Coke	1	11	0
Flux and sundries	0	11	6
Electrodes	1	4	6
Labour	0	3	0
Electrical Energy	2	0	0
Total Cost	£5	18	0

If electrical energy could be supplied from gas-driven generators at 0·125 pence per unit, the price would be reduced to £5 9s. per ton, though even this would still be higher than the cost of steel produced by the more orthodox methods. Possibly, however, some special steels which are costly to produce

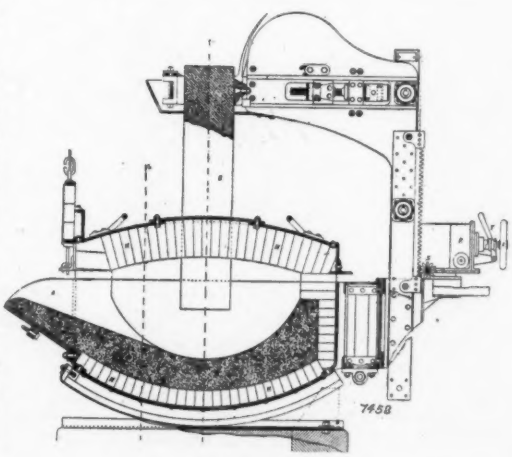


FIG. 2.—HÉROULT FURNACE.

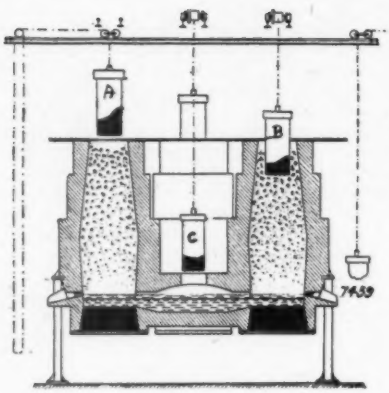


FIG. 3.—KELLER FURNACE.

would lend themselves to electrical production, one example being very pure steel of high tensile strength which has already been employed in the manufacture of tubes subjected to very high pressures.

A furnace which has recently given excellent results is the "Kjellin" furnace* at Gysinge in Sweden. Although this furnace gives a very good result, based on the horse-power hours per ton in Table I., it does not necessarily indicate superior efficiency as the charge was partially reduced, which was not the case with the other examples. Several linings have been tried, but basic magnesite lining has so far proved most suitable; about 280 tons have been made during a twelve weeks' run with one lining. As electric reduction is not considered profitable for the early stages of the process, the pig is produced by a blast furnace in the ordinary way. Several methods were tried, but obviously the most economical method is to tap the blast furnace direct into the electric furnace, thus saving the heat in the molten metal.

TABLE III.—230 H.-P. ELECTRIC FURNACE.

Horse-power hours per Ton of Metal Produced.	Power cost at ½d. per Unit.	Power cost (Actual).	Nature of Charge.
	s. d.	s. d.	Cold Pig Iron.
1030	16 0	5 2	1430 lbs molten pig
880	13 6	4 4	2800 lbs. cold pig and scrap.

* See ENGINEERING REVIEW, Vol. xi., p. 341.

The advantages of introducing a molten, or partially melted, charge will be apparent from Table III., where charges of between three and four tons are dealt with.

Power in this case is supplied from a waterfall at £2 6s. per horse-power year, and the total cost of the steel is £7 10s. per ton. This latter figure is out of proportion to costs at other places, and appears to be accounted for by the high cost of coke and electrodes, both of which may, and often do, bulk more largely in the cost than the electric power.

In countries where fuel is cheap and water-power scarce, electric smelting and refining is less likely to develop, except on special steels, as the cost of power becomes almost prohibitive. In Europe there are waterfalls both in Norway and in the Alps, where a horse-power year of 8,760 hours costs only 19s., but at Rheinfeilden it reaches £6. At Niagara Falls it varies from £3 11s. to £4 3s. In this country, with steam-power and triple expansion engines, it is £6 to £8, though at the pits' mouth, with cheap coal, it may be supplied at a cost of £4 15s., and with a gas-power plant at a still lower figure.

It seems that the most likely development will be with ordinary smelting in the blast furnace which is tapped direct into the electric furnace, the waste gases from the blast furnace being used in gas engines driving electric generators which supply electrical energy for the production of the steel. The fuel charges would then be largely eliminated, and capital costs only would dominate the question. From a commercial standpoint it is doubtful if such a station could be built and equipped even on a large scale for less than £12 per horse-power, which would make the fixed charges, taking them at 7½ per cent. on the outlay, 18s. per horse-power year, though a certain proportion of stand-by plant would raise this figure by an amount depending on the size of the station, but it is safe to figure the horse-power year under such circumstances as being approximately £1. Taking this figure as a basis, it will be seen that we, in this country, need not fear the development of electro steel works in other countries, for given developments in this country along the lines just indicated, it appears that we can easily compete with the cheapest water-power, especially as electrodes often figure quite as heavily as power in the cost of producing the steel, and these can be made at a lower cost in this country than in any other, except perhaps Germany.

By PERCY LONGMUIR.

STEEL: ITS PROPERTIES AND TREATMENT.

The Injurious Effect of Acid Pickles on Steel.*—Professor Burgess in continuing his studies of pickling processes deals specifically with the injurious effect of such treatment on the physical properties of the metal. That iron is weakened by superficial loss after immersion in an acid solution is familiar, but it is not so generally recognised that a more serious effect is found in the alteration of physical properties below the surface. The effect of the acid penetrates to some depth, and this phenomenon is commonly designated as "rotting." Various workers have noted this deterioration, but the consensus of opinion among these investigators is that the alteration in physical properties of iron or steel by the action of acids is due to the hydrogen which is liberated. The only dissension from this view is that which holds that the acid itself penetrates into the metal through capillary or other force, the destructive action being thus continued after the metal has left the pickling solution. The absorption or occlusion of hydrogen by iron has been studied and its effect noted by many investigators. Granting that the hydrogen liberated upon the iron is alone responsible for the rotting produced in the pickling process, the remedy would naturally be sought in some method which would suppress the hydrogen and at the same time would not interfere with the effectiveness of the pickle in removing scale. Passing to the experimental methods of the paper the deteriorating effect of a pickling solution may be estimated as in Fig. 1. In this a flat steel strip or piece of wire is bent and supported as shown and immersed in the acid under test. After a certain time the sample will become brittle and break. The time required to produce this effect in different solutions gives the relative deteriorating effects of each, and these may be approximately stated as being inversely proportional to the periods thus measured. A more satisfactory method consists in determining the amount of flexure which a strip of steel will stand before and after being subjected to various corroding influences. Fig. 2 shows a device designed for this purpose. The strip is held in the manner shown, and the number of turns on the screw head required to effect rupture give a determination of the amount of bending which the strip will stand. When making tests the screw must be turned uniformly; if not, erratic results follow. In using the apparatus the decrease in flexibility was taken as being a measure of the deteriorating effect of hydrogen. In the following results this deterioration is expressed as "percentage-deterioration" in order to express measurements which show roughly the amount of deterioration, by means of which comparison between the different tests may be made.

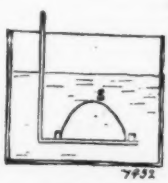


FIG. 1.

These results lead to the conclusion that sulphuric acid produces less deterioration than

FIG. 2.

* *Electro Chemical and Metallurgical Industry*, No. 1, Vol. iv.

Acid Solution.	Time of Immersion. Minutes.	Per cent. Deterioration.	Weight before Corrosion.	Loss.
Normal Sulphuric ...	10	3?		
,, Hydrochloric	10	59	Grams	Grams
,, Sulphuric ...	15	61	6·8162	0·0313
,, Hydrochloric	15	67	6·8160	0·0314
,, Nitric	15	13	6·8080	0·2540
,, Sulphuric ...	20	55		
,, Hydrochloric	20	69		
,, Sulphuric ...	30	57		
,, Hydrochloric	30	68·5		

does hydrochloric, though the difference between the two is not great. The brittleness is shown to be produced mainly during the first few minutes of immersion, the values upon longer immersion remaining somewhere near constant. Deterioration in the case of nitric acid, 13 per cent., is probably low, since the amount of metal dissolved made the strip thinner, and therefore capable of a greater amount of bending without rupture. In fact if the strip is allowed to remain a sufficient length of time in nitric acid the bending of the corroded sample becomes greater than that of the uncorroded sample. This is illustrated in the following results :—

Minutes Immersion.	1.	3.	5.	10.	15.	20.	30.	60.
	Per cent.							
Normal Sulphuric ...	1·0	3·8	15·2	25·0	21·6	11·5	38·0	58·0
Normal Hydrochloric	9·8	9·4	32·0	49·0	53·3	47·9	63·0	65·6
Normal Nitric ...	11·0	12·7	5·3	18·0	23·0	5·5	−3·0	−2·0

Here again sulphuric acid produces less brittleness than does hydrochloric, and the lower amount of brittleness with nitric acid is not due to lack of hydrogen evolution alone but to the fact that the rate of dissolution of the metal is greater, and the decrease in thickness producing greater flexibility. Apparently there is a maximum effect between ten and fifteen minutes' immersion for all samples, after which there is first a decrease and then an increase. Whether this is an accidental effect or whether it is due to a definite phenomenon requires further experimental data to determine. The presence of arsenic in sulphuric acid causes the acid to act with less rapidity than a pure solution. Experiments with a five normal solution of sulphuric acid containing a small quantity of arsenious acid gave the following results :—

PERCENTAGE DETERIORATION.

Minutes immersion.	3.	10.	15.	60.
5*n*, H_2SO_4	52·0	54·8	61·0	64·0
5*n*, H_2SO_4, As_2O_3 ...	0·8	8·0	2·0	9·2

These results show the advantage of the presence of arsenic, and it is noted that the surfaces were equally clean in both cases : in fact the solution containing arsenic gave a smoother surface than that left by the arsenic free solution. Further experiments are quoted which show the marked retardation of corrosion where arsenic is employed, and in every case the brittleness of the sample is much less than when arsenic free acid is used. The precise reason for the protective effect of arsenic cannot yet be stated, and it is possible that certain other impurities might be introduced to greater advantage. This is a problem worthy of further investigation.

The Influence of Nitrogen on Iron and Steel.—In the foregoing the deleterious effect of hydrogen is well shown, and apparently nitrogen when present in iron or steel has an equally bad effect. Whilst the exact influence of nitrogen is to some extent unknown, evidence extant indicates it to have a distinct hardening and embrittling effect. Recently interest in nitrogen has revived, and from a lengthy course of reading we condense the following :—According to M. Hjalmar Braune* accidental fragility in soft iron or steel is occasioned by the presence of nitrogen absorbed during fabrication of the metal. Nitrogen thus absorbed is held in solution by the ferrite, of which it lowers the fusion point and at the same time lessens the solubility for carbon. In ascertaining the effect of varying amounts of nitrogen a series of test bars were heated to a temperature of 800° C. in an atmosphere of ammonia for varying lengths of time according to the extent of absorption required. After this treatment the bars were packed in sand, enclosed in an iron box, and annealed in order to obtain a homogeneous distribution of the combined nitrogen. The test pieces, essentially soft iron, had originally the following composition :—Carbon, 0·06 per cent.; silicon, 0·01 per cent.; manganese, 0·06 per cent.; sulphur, 0·005 per cent.; phosphorus, 0·05 per cent.

The effect of varying contents of nitrogen on the mechanical properties of this iron is shown in the appended table.

No.	Nitrogen. Per cent.	Tonne par Cm_2.		Elongation. Per cent.
		Elastic Limit.	Max. Stress.	
1	0·015	23·2	33·9	34·7
2	0·015	24·0	34·3	33·7
3	0·015	23·9	33·5	33·1
4	0·028	26·2	34·1	32 0
5	0·028	26·0	33·4	27·5
6	0·044	27·0	36·5	29·9
7	0·060	27·8	35·3	30·3
8	0·060	29·4	37·7	28·1
9	0·075	27·3	36·0	28·0
10	0·100	27·4	36·5	23·0
11	0·120	31·4	40·2	18·0

* *Revue de Métallurgie*, Vol. ii., No. 7.

Micrographic examination shows a transformation of the metal as the content of nitrogen increases. Thus the ferrite crystals progressively diminish in size and some of them become marked by parallel striæ. When the content of nitrogen reaches 0·07 to 0·08 per cent. the crystals become very small, hardly one-tenth of their original linear dimensions, and at the same time the cement between the crystal junctions increases in thickness. Once this structure is developed the metal is completely fragile. It may be added that a content of 0·07 per cent. nitrogen is only rarely met with in industrial products. In order to study the effect of varying contents of nitrogen on hard steels a sample containing 1·15 per cent. carbon was selected and test bars treated as before in an atmosphere of ammonia. The results are on the whole comparable to those obtained from the first series. Elongation is diminished and at a content of 0·030 to 0·035 per cent. nitrogen is almost completely annulled, the steel then being quite fragile. Nitrogen exercises a considerable influence on the properties of quenched steels, and in this case nitrogen is stated to be held in solution by martensite instead of the ferrite of annealed steels. The effect of nitrogen on electric and magnetic properties is equally of moment, in soft irons especially coercive force and hysteresis are increased.

A second paper by the same author forms an inaugural thesis submitted to the University of Basel.* It covers very similar ground to the foregoing except that the method employed for estimating nitrogen is fully described. The increase in specific resistance of an iron wire (0·08 per cent. carbon) after nitrifying to the extent of 0·267 is equivalent to 32·6 per cent. Magnetic tests show that the influence of nitrogen is somewhat similar to that of carbon, the saturation is more feeble but the magnetism is more important.

Comparison between Bessemer and Siemens Martin Steel. — This memoir by Dr. Tholander appeared in *Jernkonterets Annal* in 1888 and has recently been translated into the *Revue de Métallurgie*,† by M. Hjalmar Braune. Notwithstanding its early publication the paper possesses much of direct interest. The author commences by stating that Bessemer steel cannot be produced of equal quality to Siemens Martin steel and that this difference cannot be explained by ordinary chemical analysis. It has often happened that a Bessemer steel refused as hard and fragile may have had a better chemical composition than a soft and tenacious Siemens Martin steel. In the Bessemer process nitrogen passes through a bath of molten metal whilst in the Siemens Martin nitrogen touches only the surface of the slag protecting the bath. The inference is that Bessemer metal is richer in nitrogen than Siemens Martin metal of similar grade. A series of analyses for nitrogen seemed desirable and were accordingly made on a variety of steels. The method employed, that of Boussingault, is based on the principle that a solution of nitride of iron in sulphuric acid results in the formation of ammonia. Should the nitrogen exist as cyanide. ammonia is also formed on dissolution in sulphuric acid. This ammonia is then estimated by titration. The purification of reagents and full details of the method are given. From the many analyses recorded it is readily apparent that Bessemer steel is higher in nitrogen than Siemens Martin steel. Thus summarising the results the series on Avesta Bessemer steels show contents of nitrogen ranging from 0·012 to 0·022 per cent. Soft Siemens steels of Hammarby give from 0·005 to 0·006 per cent., whilst crucible steels of Vikmanshyttan give from 0·006 to 0·008 per cent. nitrogen. By cementing a soft steel in ferrocyanide the nitrogen was raised to 0·31 per cent. It is noted that in overblowing a Bessemer charge, after the removal of carbon, the oxygen of the blast will combine with iron, leaving almost chemically pure nitrogen to pass through the metal.

Dr. Tholander's paper is followed by Boussingault's memoir of 1861 on the estimation of nitrogen, and this in turn is followed by a translation of Allen's well-known paper, read before the Iron and Steel Institute in 1880. As a conclusion to these articles Professor Le Chatelier* offers a few remarks on the question of nitrogen in steel. Massing the results already obtained, it is evident that the difference in contents of nitrogen bears some relation to the particular method of production. Thus Bessemer steel is higher in nitrogen than Siemens steel, and cemented steel is highest of all. The experiments of M. Braune show a correlation between structure and nitrogen content, and the same experiments render probable the existence of a considerable influence on the mechanical properties of iron and steel. Finally, late researches, not yet published, appear to indicate that the use of Nessler's reagent in estimating nitrogen does not always give concordant results. However, the studies now in progress will, it is anticipated, give definite answers to the points at present in suspense.

The Electric Smelting of Iron and Steel.†—Electro-thermic processes are of very considerable interest, not only owing to the developments which have occurred during the last few years, but also owing to the effect these processes may have on future metallurgical industry. What that future may be, time alone will tell; however, in a paper presented to the Students' Engineering and Metallurgical Society‡ Mr. R. Mather clearly indicates the

* *Métallurgie*, Vol. iii., No. 2.
† *Revue de Métallurgie*, Vol. ii., No. 12.

* *Revue de Métallurgie*, Vol. ii., No. 12.
† See also Electrical Notes section, pp. 219.
‡ Sheffield University.

present position of electro-thermic processes and to some extent possible development as far as the metallurgy of steel is concerned. At the outset the paper opens with a short account of the growth of electric smelting and this is followed by admirable descriptions of the various processes possessing a practical value. After describing these processes the author passes on to a general comparison between electric smelting and the more usual methods of producing steel. The first advantage of any electro-thermic process is found in its freedom from gases, a feature of special moment in determining the sulphur content of a steel. This absence of sulphurous gases allows the fluid bath to soak until thoroughly dead melted, without contamination, thereby leading to increased soundness. The heat efficiency of an electric furnace compares favourably with that of the open hearth furnace, whilst it is superior to that of the ordinary coke fired crucible furnace. Thus Kjellin from his first furnace obtained an efficiency of over 40 per cent., and this when working on a small output owing to lack of sufficient power. Héroult and Stassano give similar figures for their processes. This high efficiency is due to the fact that in every process except the Stassano the heat is produced in the metal itself and also to the fact that there are practically no gases to carry away the heat. Under these conditions a good efficiency should be obtained, and there is reason to believe that the figures quoted will meet with improvement in the larger type of furnaces now being constructed. As regards development it is readily admitted that electric reducing furnaces cannot compete with the blast furnace when the latter is favourably situated as regards fuel. However, in this direction there are many possibilities in countries having iron ore, good water supply for generating power, and scanty fuel supply. These conditions are also equally favourable for steel making, but it is further claimed that a considerable field for electric furnaces may be found in Britain, Germany and the United States. Naturally in the production of structural steels, the Bessemer converter and the modern open hearth furnace are unrivalled, but in the production of special quality steels, tool steels, alloy steels and the like, furnaces of the Kjellin and Héroult type have been found to yield satisfactory commercial results. These furnaces do compete with the crucible process, and as the author pertinently shows, further economies in the cost of power may be anticipated as a result of the development of cheap power gas.

The working costs of a process are, of course, only one factor, a second is found in the quality of the product, and here the evidence adduced by the author shows that temper for temper the properties of electric furnace steels compare very favourably with those of crucible steels. The final test is not in tensile or chemical properties so much as endurance under actual working conditions, and on this aspect comparatively little has been published. To meet this deficiency Professor Arnold has appointed a committee of the society to practically investigate the properties of a series of Kjellin steels, and compare them under working conditions with similar steels of crucible make.

Electric Smelting of Iron Ore.*—A preliminary report by Dr. Day, of the United States Geological Survey records a series of experiments on the utilisation of black sands and magnetic iron ores obtained from various parts of the Pacific Coast. The first experiments were conducted in a small furnace built as follows: A cast-iron plate, ¾ in. thick and 3 ft. square was bedded on a single course of firebrick. On this an oval sheet-iron drum 3ft. long and 3 ft. high was placed, and lined inside with firebricks, to form a crucible 18 in. square and 24 in. high. The bottom of this crucible was formed of broken carbon electrode, and a tapping hole was placed level with the top of this carbon. A carbon electrode was suspended above the furnace and connected with a balanced axle and wheel, thus permitting of movement up and down. Alternating current of 1,000 to 2,000 amps. at 50 to 20 volts was available at the terminals. The first charge consisted of a mixture of 200 lbs of magnetite, 44 lbs. of coke containing about 25 per cent. of ash, and 24 lbs. of lime. About 150 lbs. of this mixture was slowly introduced into the furnace, and within an hour some 70 lbs. of steel and slag were tapped from the furnace. A second run of two hours gave 90 lbs. of steel from 300 lbs. of ore. These experiments being successful, a similar, but larger furnace was built, and further experiments made. From the daily records of both furnaces it appears that the energy consumption per unit of weight of steel produced varied greatly with the amount of the charge and other factors; 1 H.P. day producing from 2 lbs. to 24 lbs. of steel. In concluding this note we venture to think that though the term "steel" is used in describing the product, this should really be indicated as "cast-iron," as the material would be highly carburised.

FOUNDRY PRACTICE.

Experimental Desulphurisation.—Efforts already noted in this direction have, on the whole, shown that the addition of manganese ore to the cupola charge effected a certain lowering in the sulphur content of the resulting castings. In a series of experiments recorded by Mr. R. Meeks in the *Iron Age* this reduction has not been effected, and his results are therefore worthy of study in that they differ from others previously noted in these columns. The experiments were made in a car wheel foundry, the cupola used having an internal diameter of about 68 in., and the charges consisting of 425 lbs. coke, 4,400 lbs. of iron. No

* *Electro-Chemical Metallurgical Industry*, Vol. 1., No. 4.

reduction in the content of sulphur was obtained by the use of limestone, and the charges of stone were gradually increased from 100 lbs. to 400 lbs. without obtaining any beneficial result. An adverse result was found in the corroding effect of the limestone on the lining. The experiments show that limestone as a flux is excellent, but as a desulphuriser it is useless. Experiments with manganese ore proved no better, and whilst a large series of experiments yielded a reduction of 0·02 per cent. in sulphur this decrease is practically nil, as far as desulphurisation is concerned and may have been due to other causes. Turning to positive methods of sulphur removal the writer believes that there are only two, viz. :—(1) the use of ferro-manganese in the ladles or in the cupola ; and (2) the use of low sulphur materials throughout. Whilst the latter cannot exactly be termed sulphur removal, it is nevertheless a fact that the less sulphur entering the cupola the better the result

Improved Air Furnaces.—In the current issue of *The Foundry*, Mr. N. W. Shed suggests several improvements for increasing the efficiency of the ordinary air furnace. Briefly summarised these resolve into the following :—First the introduction of forced draught either by means of steam jets or by means of air blast. To utilise the waste heat of the stack preheating the air blast is suggested. This involves the provision of two regenerator chambers as in the open hearth furnace. It is claimed that the improved combustion in a furnace of this style would bring the heating power of the flame nearer to the bridge and for the same tonnage as the old style of air furnace, the area of the bed and fire-box could be reduced by one-fourth. If a furnace of this type could be continuously operated melting costs would approach those of the cupola, whilst at the same time the quality of the product would be far superior to that of cupola metal.

Permanent Moulds.—This subject is of keen interest to all founders, many of whom have expended considerable time and thought in efforts to solve the problem of permanent moulds. Our own efforts in this direction have included silica, carbon and metallic chills, and it need not be stated that no fruitful result has been obtained. Turning to a paper by Mr. Caldwell, before the Philadelphia Foundrymen's Association,* we note that essentially the moulds are formed of carbon. This carbon is prepared at a higher temperature than that of the metal to be cast in the mould. The moulds are baked at a very high temperature, and it is stated that a mould baked at a temperature of 4,000° Fahr. will withstand any molten metal up to and including steel. Such moulds do not expand or contract, and appear to get into better condition by use. The particular method of obtaining the high carbonising temperature as also the high baking temperature without injury to the moulds is not stated, and the writer naively adds that he is not yet "through the Patent Office." However, the matter as given is extremely suggestive, and further details will be awaited with interest.

Practical Alloying. — Dealing with foundry mixtures Mr. J. F. Buchanan* gives a series of commercial alloys, in which scrap or old metals largely figure as constituents. Thus brazing metal may be easily made by adding to molten copper from one to three times its bulk of brass tubing or sheathing. A common practice in making cheap gun metal is found in melting a quantity of mixed brass and adding to it an equal quantity of standard gun metal. A good antifriction alloy is obtained from 100 parts of lead shot and from 6 to 10 parts of antimony. The arsenic present in the lead shot has a good influence on the antifriction properties of the resulting alloy. A reliable acid resisting alloy is made from three parts of copper and one part of antimonial lead. Good steam metal may be made by adding 15 per cent. plumber's fine solder to molten brazing metal. Finally, the writer emphasises the necessity of careful attention to detail in making alloys, and the practice followed in melting largely determines the success or otherwise of the resulting alloy.

The Prevention of Porous or Unsound Brass Castings.—According to Mr. H. P. White in the January *Foundry* the porosity of brass castings is due to the presence of an oxide or oxides. The remedy lies in deoxidising the contents of the crucible by means of phosphorus, and each crucible should be so treated.

GENERAL METALLURGY.

Notes on Metals and their Ferro-Alloys used in the Manufacture of Alloy Steels.—Dr. Steinhart, in a comprehensive paper read before the Institution of Mining and Metallurgy, deals admirably with the "special" metals or alloys used in steel-making. At the outset the necessity for pure alloys is emphasised, and from the steel-makers' point of view these alloys must be free from or low in sulphur and phosphorus, and in certain cases low in carbon. Nickel, the first metal described, is dealt with at length, the ores and their metallurgical treatment being fully indicated. Among the analyses given the high purity of "Mond" nickel is worthy of note, and is exemplified in the following :—

Nickel	99·78 per cent.
Copper	0·015 ,,
Iron	0·161 ,,
Sulphur	Nil.
Carbon	0·060 ,,
Silicon	0·027 ,,

* *The Iron Trade Review*, No. 2, Vol. xxxix.

* *The Foundry*, January, 1906.

Ferro-chromes are chiefly obtained from chrome iron ore or chromite, containing when pure 68 per cent. chromic oxide. New Caledonian ores of 56 per cent. chromic acid are by no means uncommon, and may be purchased at English or Continental ports at about 70s. per ton, with a corresponding increase for each unit above 50 per cent. Early ferro-chromes of from 50 to 60 per cent. chromium, were made by reducing chromite with charcoal in a brasqued crucible. Later the reduction was effected in small blast furnaces; but these are now replaced by the electric furnace. Analysis of an American ferro-chrome shows 72·7 per cent. chromium and 5·3 per cent. carbon. Two analyses of French samples give 65·3 per cent. Cr, 6·1 per cent. C; and 64·45 per cent. Cr and 8·95 per cent. C respectively. Types of very pure alloys, produced by the Giffre Electro Chemical Co., show in one case a carbon content of 0·555 per cent., and the second a content of 1·271 per cent.

These figures are remarkably low, and as a result, the first alloy is valued at about £150 per ton, whilst the second one realises about £90 per ton. As to the actual method of production nothing can be stated, but the reaction shown by Moissan is worth noting.

$$3\,Cr_2\,C + Cr_2\,O_3 = 14\,Cr + 3\,CO.$$

In this case excess of chromite acts as a decarburiser. The Goldschmidt method is also indicated by which practically metallic chromium is obtained, analysis showing in one case 97·41 per cent. chromium and in another 99·55 per cent.

The chief source of tungsten is found in the ore wolframite, which should be as free as possible from tin, arsenic, sulphur, and phosphorus. Tungsten powders, produced by the Tungsten and Rare Metals Company, show in one case a tungsten content of 97·02 per cent. and in another of 98·63 per cent. In reducing the ore, it is first ground to a powder and fused with sodium carbonate, in order to form tungstate of soda. The product, which also contains FeO, MnO, $Al_2\,O_3$, SiO_2 and any SnO_2 present, is again crushed, leached with boiling water, and the oxides left behind in the filter press. The solution of sodium tungstate is treated with hydrochloric, in order to precipitate the yellow tungstic acid, which is collected, dried, and reduced in crucibles to metallic tungsten. Ferro-tungstens are also a product of the electrical furnace, but according to the author the samples so produced are variable in quality. The annual production of tungsten approaches 1,500 tons, of which this country (chiefly Sheffield) consumes nearly two-thirds.

The chief ores of molybdenum are molybdenite $Mo\,S_2$ and wulfenite $Pb\,Mo_4$, both comparatively rare minerals. Analysis of French ferro-molybdenum, an electric furnace product, show in one case 87·5 per cent. molybdenum, 6·4 per cent. iron, and 6·3 per cent. carbon. Another sample gives approximately 78·5 per cent. molybdenum, with carbon under 2 per cent., a distinct amount of sulphur, and the balance iron. Thermite, Ltd., produce a metal of 98 to 99 per cent. purity, and also compound alloys of molybdenum, chromium, and nickel.

The most important ore of vanadium is vanadinite, which in the pure state should contain 19·35 per cent. $V_2\,O_5$; but ores commercially used only contain about 10 per cent. $V_2\,O_5$. A process of extraction, described by H. Procter Smith, consists in melting vanadinite with nitre cake, which separates lead, and on extraction with water a solution containing sulphate of vanadium and iron is obtained. To this scrap iron is added, in order to reduce any higher oxides of vanadium. Precipitation with Na OH gives a mixture of oxides of vanadium and iron. This mixture may be reduced either in the electric furnace, or by means of the Goldschmidt aluminium reduction process. In producing ferro-titanium, A. Rossi reduces rutile, chiefly $Ti\,O_2$ and iron, in an electric furnace, with the aid of aluminium; and the resulting ferro, containing from 10 to 12 per cent. titanium, is used for raising the tensile strength of cast-iron. It is said that cobalt may be used for similar purposes as nickel; but unless it offers material advantages over the latter, its enhanced price will restrict its application.

Book Reviews.

Concrete-Steel. By W. Noble Twelvetrees, M.I.M.E., A.M.I.E.E. (London: Whittaker & Co.) 218 pages, 73 illustrations, and 28 tables. Price, 6*s.* net.

This little book aims at setting before the reader such information regarding that combination of steel and concrete known variously as concrete-steel, ferro-concrete, and reinforced concrete, as will enable him to grasp thoroughly the principles which must underly its use, and then to put these principles to practical use.

That concrete-steel has some marked advantages over other building materials there is no doubt. The steel will not rust, and the concrete itself is practically unaffected by the climatic conditions. Unless made with limestone it seems to be almost unharmed by fire. As illustrating its fire-resisting qualities it may be mentioned that in the United States the usual fire insurance rate for concrete-steel buildings is about one-half that of buildings used for the same purposes but constructed on the "slow-burning" principle. As regards the cost, a great deal depends on the local prices for materials. Some tenders for buildings in America seem to show that it is from 5 to 15 per cent. more expensive than a "slow-burning" structure, but less expensive than a composite structure of steel beams and concrete floors.

In Chapter I. the author gives a review of the known properties of concrete without any reinforcement, very wisely laying emphasis on the necessity for the greater care in the choice of the constituent materials and their subsequent mixing. The wide variations observed in the strength of concrete do more, probably, than anything else to retard its more extended use in building constructions, as they make for expense and uncertainty as to the results.

After devoting a chapter to the consideration of the properties of steel, the author passes on to a consideration of the generally accepted theories on which the calculations for concrete-steel are based. The generally accepted theory is that we may have the neutral axis of a beam at any height we please by the use of a suitable proportion of steel reinforcement in the tension area. Above the neutral axis the concrete is in compression, but below the neutral axis the concrete is looked upon as forming merely a geometrical connection between the steel (which takes all the tensile stress) and the concrete in compression, but not in any way carrying any part of the load. That this is a very satisfactory theory the author would probably be first to deny, yet it is used as the basis of almost all concrete-steel calculations. The theory of Professor Hatt, in which all the concrete assists in carrying the load, seems very much more satisfactory, but as yet it lacks sufficient experimental evidence to make it generally acceptable. There is really nothing for it in the present state of our knowledge, but to rely on empirical formulæ based on experience. In concrete-steel calculations the factor of safety is in truth a factor of ignorance. Before passing on to consider the other features of the book we must enter an emphatic protest against the author's method of calculating the position of the neutral axis in a simple concrete beam, as given in Article 32.

The author treats very fully, and illustrates by numerous numerical examples, the design of concrete-steel beams, braced girders, floor-panels, continuous floors, piles, and columns. The student who wants to bring his knowledge of concrete-steel construction up to date, and the builder who wants to know how to apply it in practice, will find much in this book to satisfy their wants. It is clearly written and thoroughly practical.

Mechanical Appliances, Mechanical Movements, and Novelties of Construction. By Gardner D. Hiscox, M.E. (London: Archibald Constable & Co.) 396 pages, and about 1,000 illustrations. 12*s.* 6*d* net.

This book is an elaboration of certain features of the author's former work on "Mechanical Movements," which has passed through ten editions. It describes briefly and lucidly close on a thousand mechanical constructions of very different types, including a number of contrivances intended for the discovery of perpetual motion, the search for which, however, the author very wisely discourages.

The different mechanical constructions are classified into twenty-three sections, and include such widely different things as locomotives, agricultural implements, well-boring tools, draughting appliances, torpedoes, whistling buoys, an electric incubator, telephones, and opening bridges, to mention only a few. The compilation is thoroughly up to date, as is evidenced by descriptions and illustrations of steam turbines, gasoline engines, a Mond gas producer plant, flying machines, Hele-Shaw's friction clutch, wireless telegraphy apparatus, oil-fuel burners, automobile parts, and other modern constructions.

The book contains a large amount of useful and interesting information for engineers and all interested in mechanical constructions. The book is well got up, and the illustrations—of which there are about a thousand—are remarkably good.

List of Publications the principal contents of which are regularly indexed.

American Engineer and Railroad Journal, 140, *Nassau Street, New York* ... ... 20 cts.
American Machinist, 218, *William Street, New York* ... ... 4d.
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